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PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXLIV.

PART I.

LONDON:
PRINTED BY RICHARD AND JOHN E. TAYLOR, RED LION COURT, FLEET STREET.
MDCCCXLIV.

ADVERTISEMENT.

The Committee appointed by the *Royal Society* to direct the publication of the *Philosophical Transactions,* take this opportunity to acquaint the Public, that it fully appears, as well from the Council-books and Journals of the Society, as from repeated declarations which have been made in several former *Transactions,* that the printing of them was always, from time to time, the single act of the respective Secretaries till the Forty-seventh Volume; the Society, as a Body, never interesting themselves any further in their publication, than by occasionally recommending the revival of them to some of their Secretaries, when, from the particular circumstances of their affairs, the *Transactions* had happened for any length of time to be intermitted. And this seems principally to have been done with a view to satisfy the Public, that their usual meetings were then continued, for the improvement of knowledge, and benefit of mankind, the great ends of their first institution by the Royal Charters, and which they have ever since steadily pursued.

But the Society being of late years greatly enlarged, and their communications more numerous, it was thought advisable that a Committee of their members should be appointed, to reconsider the papers read before them, and select out of them such as they should judge most proper for publication in the future *Transactions*; which was accordingly done upon the 26th of March 1752. And the grounds of their choice are, and will continue to be, the importance and singularity of the subjects, or the advantageous manner of treating them; without pretending to answer for the certainty of the facts, or propriety of the reasonings, contained in the several papers so published, which must still rest on the credit or judgement of their respective authors.

It is likewise necessary on this occasion to remark, that it is an established rule of the Society, to which they will always adhere, never to give their opinion, as a Body, upon any subject, either of Nature or Art, that comes before them. And therefore the thanks, which are frequently proposed from the Chair, to be given to the authors of such papers as are read at their accustomed meetings, or to the persons through whose hands they received them, are to be considered in no other light than as a matter of civility, in return for the respect shown to the Society by those communications. The like also is to be said with regard to the several projects, inventions, and curiosities of various kinds, which are often exhibited to the Society; the authors whereof, or those who exhibit them, frequently take the liberty to report and even to certify in the public newspapers, that they have met with the highest applause and approbation. And therefore it is hoped that no regard will hereafter be paid to such reports and public notices; which in some instances have been too lightly credited, to the dishonour of the Society.

The Meteorological Journal hitherto kept by the Assistant Secretary at the Apartments of the Royal Society, by order of the President and Council, and published in the Philosophical Transactions, has been discontinued. The Government, on the recommendation of the President and Council, has established at the Royal Observatory at Greenwich, under the superintendence of the Astronomer Royal, a Magnetical and Meteorological Observatory, where observations are made on an extended scale, which are regularly published. These, which correspond with the grand scheme of observations now carrying out in different parts of the globe, supersede the necessity of a continuance of the observations made at the Apartments of the Royal Society, which could not be rendered so perfect as was desirable, on account of the imperfections of the locality and the multiplied duties of the observer.

A List of Public Institutions and Individuals, entitled to receive a copy of the Philosophical Transactions of each year, on making application for the same directly or through their respective agents, within five years of the date of publication.

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Switzerland.

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Belgium.

The Royal Academy of Sciences at Brussels.

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The Batavian Society of Experimental Philosophy at Rotterdam.

Spain.

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Portugal.

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The Royal Academy of Sciences at Paris.
The Imperial Academy of Sciences at St. Petersburgh.
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ROYAL MEDALS.

HER MAJESTY QUEEN VICTORIA, in restoring the Foundation of the Royal Medals, has been graciously pleased to approve the following regulations for the award of them:

That the Royal Medals be given for such papers only as have been presented to the Royal Society, and inserted in their Transactions.

That the triennial Cycle of subjects be the same as that hitherto in operation: viz.

1. Astronomy; Physiology, including the Natural History of Organized Beings.
2. Physics; Geology or Mineralogy.
3. Mathematics; Chemistry.

That, in case no paper, coming within these stipulations, should be considered deserving of the Royal Medal, in any given year, the Council have the power of awarding such Medal to the author of any other paper on either of the several subjects forming the Cycle, that may have been presented to the Society and inserted in their Transactions; preference being given to the subjects of the year immediately preceding: the award being, in such case, subject to the approbation of Her Majesty.

The Council propose to give one of the Royal Medals in the year 1844 for the most important unpublished paper in Mathematics, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1841, and prior to the termination of the Session in June 1844.

The Council propose also to give one of the Royal Medals in the year 1844 for the most important unpublished paper in Chemistry, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1841, and prior to the termination of the Session in June 1844.

The Council propose to give one of the Royal Medals in the year 1845 for the most important unpublished paper in Astronomy, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1842, and prior to the termination of the Session in June 1845.

The Council propose also to give one of the Royal Medals in the year 1845 for the most important unpublished paper in Physiology, including the Natural History of Organized Beings, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1842, and prior to the termination of the Session in June 1845.

The Council propose to give one of the Royal Medals in the year 1846 for the most important unpublished paper in Physics, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1843, and prior to the termination of the Session in June 1846.

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The Council propose also to give one of the Royal Medals in the year 1847 for the most important unpublished paper in Chemistry, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1844, and prior to the termination of the Session in June 1847.

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PHILOSOPHICAL TRANSACTIONS.

I. *Additional Researches on the Electrolysis of Secondary Compounds.*

By J. Frederic Daniell, *Esq., D.C.L., For. Sec. R.S., Prof. Chem. in King's College, London, and* W. A. Miller, *Esq., M.D., Dem. of Chem. in King's College, London.*

Received February 15,—Read February 25, 1844.

THE authors of the following paper having agreed to work together upon the subject of the electrolysis of secondary compounds as opened by one of them, in two letters addressed to Dr. Faraday, and honoured with a place in the Philosophical Transactions for 1839 and 1840, have arrived at some results, which probably will not be without interest to the Royal Society, and which they have now the honour to communicate.

In the two papers just alluded to, the following points were established. *First.* When aqueous solutions of the neutral metallic salts are exposed to the action of the voltaic current, they are invariably decomposed. When the metal is one of that class which does not decompose water at ordinary temperatures, it is precipitated in the metallic state at the platinode: when it is of the class which does decompose water, its oxide, with an equivalent proportion of hydrogen, appears at the same electrode. The acid at the same time is set free at the zincode, accompanied by an equivalent proportion of oxygen. *Second.* When these results are compared with those of an independent voltameter in the same circuit, it is found that a certain proportion of the force which resolves a single equivalent of a *simple*[*] electrolyte into its anion and cation, produces the resolution of a full equivalent of the *complex* electrolyte into a simple metallic cation and a compound anion. *Third.* When aqueous solutions of ammoniacal salts are electrolysed, similar results are obtained; but instead of a simple metal being disengaged at the platinode, an equivalent of ammonia, accompanied in all cases by an equivalent of hydrogen, appears at the platinode. *Fourth.* We are thus entitled to conclude that in the electrolysis of complex electrolytes, different elements travel together under the influence of the voltaic current as compound anions and cations, or as *iso-electric* bodies; that is, groups which are equivalent to each other, and to simple ions, in their relations to the electric forces.

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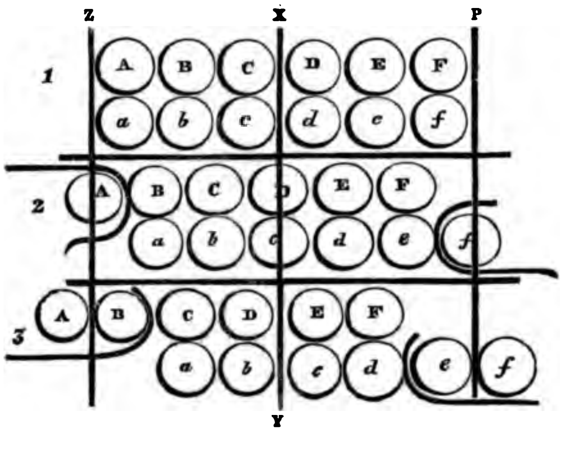
[*] By a simple electrolyte is meant one containing only two elementary substances, being the simplest form of matter capable of electrolysis.

One of the most interesting results of this investigation, was the independent confirmation which it afforded of two celebrated hypotheses, viz. that of Davy regarding the constitution of aqueo-acids, and the general analogy in the constitution of salts, whether derived from oxyacids or hydro-acids; and that of Berzelius concerning the constitution of ammonium.

It was with a view to extend our knowledge of such iso-electric groups, and to trace their connexion with chemical radicles, that we commenced our experiments.

Before we enter upon their detail, it will be best to make a few remarks upon the mode of measuring their results, which has been adopted. It is founded upon the undoubted law of definite electric action; and we have indifferently taken the amount of the ions disengaged at either or both the electrodes by the primary action of the current, or the secondary action of the elements. But there is another mode of effecting this purpose, by a diaphragm cell, in which the products of electrolysis may be kept separate; a method founded upon the hypothesis, that the voltaic decomposition of an electrolyte is not only effected by the disengagement of its anion and cation at their respective electrodes, but by the equivalent transfer of each to the electrodes; so that the measure of the quantity of matter translated to either side of the diaphragm might be taken as the measure of the electrolysis.

This was the mode which was necessarily adopted in the investigation before adverted to, where attempts were made to compare the results of the electrolysis of aqueous solutions of acids[*] and alkalies[†] with the simultaneous decomposition of saline solutions. One circumstance, however, was then overlooked, which it is necessary to attend to in making the comparison, viz. that the *disengagement* of whole equivalents of the ions at the electrodes is only accompanied, upon the hypothesis assumed, by the actual *transfer* of half an equivalent to *either* side. This will clearly appear from the following diagram.



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[*] First Letter, p. 108.

[†] Second Letter, p. 216.

Let A, B, C, &c. in the preceding diagram represent a series of particles of chlorine, *a*, *b*, *c*, &c. a series of particles of potassium in combination with the particles of chlorine in the row above them, X, Y a central line or diaphragm, and Z and P the electrodes. If 1 represent the arrangement before the current passes, the particles A and *a*, B and *b*, &c. being combined to form compound particles of chloride of potassium, 2 would represent the arrangement after a single equivalent of each ion had been disengaged at the electrodes. Each particle would thus necessarily have moved forward half a step, combining with the next adjacent particle, so that B *a*, C *b*, D *c*, &c. would now form the chain between the electrodes. If another equivalent be now supposed to be set free at each electrode, one particle of each ion would have passed the central line, one equivalent would thus be *transferred*, whilst two had been *disengaged*, as in fig. 3.

In the instances above referred to, the transfer of one quarter of an equivalent represented half of an equivalent of the hydrates respectively electrolysed. Little stress however need be laid upon this correction, inasmuch as we shall presently show that the hypothesis upon which it is founded, although generally received, is itself destitute of foundation.

1. Our first object was to ascertain more clearly than had yet been done, the influence of water in the aqueous solution of an electrolyte, by comparison with the results of the electrolysis of the same compound when in the state of igneous fusion. It had been already determined, that with regard to the *chlorides* no difference occurred, and that the amounts of chlorine evolved in the same circuit from *fused* chloride of lead[*], and from *dissolved* chloride of sodium and muriate of ammonia, were the same[†]. In the last case, ammonia and hydrogen were evolved at the platinode in equivalent proportions to the chlorine at the zincode. Here a compound cation (NH_4) was separated from an elementary anion.

When *nitrate of silver* in solution is subjected to electrolysis, the simple cation, silver, separates from the compound anion (NO_6), and upon substituting the *salt in a state of fusion*, for the solution, we obtained the same result. No gas was evolved, but *crystallized metallic silver* was deposited upon a silver platinode, which gradually increased in length, as it was slowly withdrawn from the liquid salt, just as in the analogous experiment with fused chloride of silver, devised by Dr. FARADAY. Nitrous fumes were at the same time given off from the platinum zincode in abundance. From these experiments it is evident that neither the grouping of a compound cation, nor of a compound anion, is necessarily altered by water in the transit to their respective electrodes.

2. We now turned our attention to that most interesting group of salts, the *phosphates*, which has been so ably discussed by Professor GRAHAM; not without hopes of confirming by electrolysis the beautiful theory of their constitution, which he has

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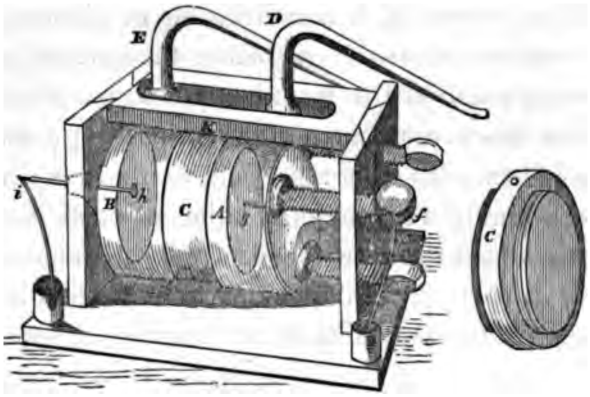
[*] First Letter, p. 108.

[†] Ibid. p. 110.

derived from considerations purely chemical. *The double diaphragm cell* which we chiefly employed in these experiments, is represented in the annexed wood-cut.



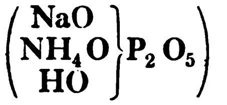
A and B are the two halves of a stout glass cylinder, accurately ground so as to fit with shoulders liquid tight. C is a hollow ring of glass, also ground on either side, with a flat shoulder to fit against the two half cylinders, which are pressed home by the screws. Each side of the ring is furnished with a rim, which is grooved to admit of a thin piece of bladder being tied over it to form a kind of drum ; at K is a small hole to admit of the cavity being filled with a liquid. D and E are two bent tubes, fitted to the two half cylinders for collecting the gases evolved in the experiments. *g* and *h* are two circular platinum electrodes connected by wires, *i*, *f* (passing through corks in the necks of the half cylinders), with the battery. The apparatus when adjusted forms three compartments, each of which may be filled with the same or a different liquid, and the whole may be supported on a light frame of wood.

We will not attempt to describe the particulars of every experiment referred to in the following pages, for their number is very great, and their details would be both tedious and useless ; we will only select some of the principal, in the results of which we can trace no ambiguity ; and have no doubt we shall obtain credit for every care in determining the purity of the substances which we employed, and in making the various analyses which were required.

(*a.*) A strong solution of *tribasic phosphate of soda and water* ($2NaO, HO, P_2 O_5$) (rhombic phosphate) was placed in the platinode cell of the diaphragm apparatus ; the centre cell and the zincode cell were both charged with a dilute solution of soda ($\frac{1}{48}$). The power of twenty cells of the small constant battery was transmitted through it, oxygen was evolved at the zincode, and in thirty-seven minutes 48 cubic inches of hydrogen were collected from the platinode ; the experiment was then stopped and the solutions examined.

The liquid from the zincode cell was carefully neutralized with nitric acid, and then gave a copious yellow precipitate with nitrate of silver, soluble in nitric acid, and in ammonia, the well-known characters of the tribasic phosphate of silver ($3AgO, P_2 O_5$). The solution in the platinode cell had become much more alkaline than at first, but when neutralized with nitric acid, gave a similar yellow precipitate with nitrate of silver. There could be no doubt therefore that *tritoxyphosphion* (or the radicle of the tritohydrate of phosphoric acid) had travelled to the zincode. The experiment was more than once repeated with unvarying results.

(*b.*) A solution of *tribasic phosphate of soda* ($3NaO, P_2O_5$) (sub-phosphate) was substituted in the same arrangement for the rhombic phosphate, and, after the action of the battery, on neutralizing the liquid in the zincode cell, a similar copious yellow precipitate was obtained from nitrate of silver.

(*c.*) To complete the series of tribasic phosphates in which different bases are substituted for each other, a solution of the *phosphate of soda, ammonia and water*  $\left(\left.\begin{matrix} NaO \\ NH_4O \\ HO \end{matrix}\right\} P_2O_5\right)$ (microcosmic salt), was subjected in the same manner to electrolysis, the zincode cell being charged with solution of soda; the solution in the zincode cell became acid to the test of litmus, and produced an abundant yellow precipitate in solution of nitrate of silver; proving that it was the tribasic acid which had travelled as before.

(*d.*) A similar arrangement was made with a solution of *dibasic phosphate* (pyrophosphate) of soda ($2NaO, P_2O_5$). Hydrogen and oxygen in equivalent proportions were respectively given out at the platinode and zincode, and the process was carried on to the same extent as before. The solution at the zincode after electrolysis was neutralized by nitric acid. When tested with solution of nitrate of silver, a copious white precipitate was formed, indicating that in this case *deutoxyphosphion* (or the radicle of the deuto-hydrate of phosphoric acid) had been transferred to the zincode.

(*e.*) A solution of *monobasic phosphate* (NaO, P_2O_5) (metaphosphate) was subjected to electrolysis under the same circumstances. The solution in the zincode cell was now found to be strongly acid instead of alkaline; when added to a solution of albumen it immediately coagulated it; and with nitrate of silver and nitrate of baryta it produced the characteristic gelatinous white precipitates, which are distinctive of the monobasic phosphates of those bases.

It was thus fully established by these experiments, and confirmed by their repetition, that the three hydrates of the phosphoric acid constitute three essentially distinct acids, which may be expressed as follows:—

$$\begin{aligned} &H + P_2O_6 \text{ proto-hydrate,} \\ &H_2 + P_2O_7 \text{ deuto-hydrate,} \\ &H_3 + P_2O_8 \text{ trito-hydrate,} \end{aligned}$$

and that when disengaged from their corresponding saline compounds by the power of the voltaic current, they travel as three distinct *oxyphosphions* in the circuit. This view, which cannot be doubted as arising from the properties of the acids so disengaged, derives confirmation from the observation that the quantity of acid transferred from the monobasic phosphate of soda was so much greater for the same amount of hydrogen disengaged, than from the dibasic and tribasic salts of the same base.

We had thus the gratification of establishing by independent testimony the correctness of Professor GRAHAM's theory of the phosphates, and it is with pleasure we also observe that his view of the basic character of water in certain saline compounds is confirmed by the results of the electrolysis of the three tribasic phosphates; from all of which the same acid was separated, notwithstanding that in two instances water obviously constituted one of the three equivalents of base. In our corresponding view, one of the three equivalents of metals was represented by hydrogen.

3. Next in natural order seems to stand the inquiry whether the salts of other tribasic acids would afford analogous results to those of the tribasic phosphates.

(*f.*) For this purpose we selected the *tribasic arseniate of potassa and water* ($KO, 2HO, As_2 O_5$) (binarseniate), the platinode cell was charged with a solution of the salt, and the zincode cell and connecting cell with solution of potassa. The combination was found to conduct very well, and oxygen and hydrogen were given off at their respective electrodes. The solution in the platinode cell assumed a grayish appearance, but there was no smell of arseniuretted hydrogen, nor was any arsenic deposited upon the electrode. The solution had become neutral to test paper. The liquid in the zincode cell was carefully neutralized by acetic acid, and afterwards produced in solution of nitrate of silver, the characteristic brick-red precipitate of the arseniate of silver ($3AgO, As_2 O_5$), so that there could be no doubt that the *tritoxarsenion* had travelled into the zincode cell.

The complicated secondary actions which take place in the electrolysis of organic compounds, and which we hope to make the subject of future communications, induce us to abstain at present from extending this part of our inquiry to the organic acids.

4. An inquiry of considerable interest now claims our attention, viz. the electrolysis of salts whose acids, having the same elementary radicle as some of those which have been already examined, are in an inferior degree of oxygenation: such are the arsenites and sulphites.

(*g.*) A solution of *arsenite of potassa* ($KO, As_2 O_3$) was carefully prepared (by dissolving single equivalents of arsenious acid and bicarbonate of potassa in boiling water), and placed in the platinode cell of the diaphragm apparatus; the connecting cell and the zincode cell were both charged with solution of potassa. During the electrolysis oxygen was given off at the zincode, but an equivalent of hydrogen was not obtained at the platinode, the electrode being covered with metallic arsenic, which was deposited in such abundance as speedily to render the liquid opake; there was no smell of arseniuretted hydrogen. This diffusion of the metal reduced by secondary action, throughout the solution, contrasts well with the compact manner in which metals are deposited, which, like copper from the neutral sulphate, are thrown down by direct voltaic action. The zincode solution was exactly neutralized by acetic acid; after which a yellow precipitate of the arsenite of silver was produced on adding nitrate of silver.

In this case, as in that of the arseniate just described (3. *f.*), free oxygen was evolved, but the corresponding hydrogen arising from the secondary action of the potassium at the other electrode was taken up in the reduction of the arsenious acid in contact with which it was evolved. No such reduction of the arsenic acid was effected.

It might have been anticipated that the oxygen in travelling with the arsenious acid to the zincode would have combined with it, and formed a portion of arsenic acid; but no such result took place: and it must be remarked, that two equivalents of oxygen instead of one would be required fully to oxidate the whole. We must, therefore, conclude that $As_2\,O_3 + O$ constitute what we may for the present distinguish as a *sub-oxarsenion.*

The experiment was repeated, by charging all the three cells of the apparatus with the solution of the salt, when oxygen was given off from the zincode as before, and arsenious acid was deposited in white crystals.

(*h.*) The *carbonates* and *oxalates* may be compared together in the same point of view as acids of the same radicle in different states of oxygenation. It has been already stated that in the electrolysis of the former, carbonic acid and oxygen were found to be given off at the zincode in equivalent proportions to the alkali and hydrogen at the platinode; proving those salts to be *oxy-carbions* of the respective metals*. When oxalate of ammonia was treated in the same way, carbonic acid alone was evolved at the zincode, and ammonia with hydrogen at the platinode*. Here the *oxalion* (or sub-oxycarbion) contains the elements of two equivalents of carbonic acid $(C_2\,O_3 + O) = 2(CO_2)$. In numerous repetitions which we now made of these experiments, we found that although in the electrolysis of oxalate of ammonia $(C_2\,O_3 + O)$ was always exactly evolved, yet that it was not invariably in the form of carbonic acid, but in different proportions of oxalic acid with free oxygen and carbonic acid. It was thus proved that the burning of the oxalic acid into carbonic acid by its associated oxygen was a secondary process, and that the $(C_2\,O_3 + O)$ which travelled in the circuit was in some way different from $2(CO_2)$.

(*i.*) A similar comparison was then made between the *sulphites* and *sulphates.* In the electrolysis of the latter, it has been shown that sulphuric acid with an equivalent of oxygen (which is evolved) travels to the zincode†. To determine the results of the former, all the cells of the diaphragm apparatus were charged with sulphite of potassa, and a voltameter was included in the circuit; hydrogen was given off from the platinode in exact proportion to that from the voltameter; but no oxygen was evolved from the zincode.

The experiment was by itself ambiguous, for it did not determine whether $(SO_2 + O)$ travelled as SO_3, or whether sulphuric acid was formed at the zincode by the secondary action of the oxygen upon the sulphurous acid. Judging from the analogy of the preceding instances, it is most probable that the oxygen with which the sulphurous acid is associated in the *sub-oxysulphion* is in a different state from that of the third equivalent in dry sulphuric acid, and that the sulphuric acid evolved at the zincode in the last experiment is the result of secondary action. Some sulphurous acid was evolved in the zincode cell, which doubtless arose from the action of the sulphuric acid upon the sulphite in contact with which it was produced.

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* Second Letter, p. 222.

† First Letter, pp. 107 *et seq.*

(*k.*) The experiment was varied by substituting *hyposulphite of soda* ($NaO, S_2 O_2$) for the sulphite, and with analogous results. Hydrogen was given off abundantly at the platinode, but no gas was evolved at the zincode. There was a strong odour of sulphurous acid at the latter, with a gradual deposition of sulphur. This doubtless arose from the secondary action of the sulphuric acid, which was first formed upon the salt with which it was in contact, by which hyposulphurous acid was disengaged, and immediately decomposed. The constitution of the hyposulphite being ($NaO, S_2 O_2$), that of the corresponding sub-oxysulphion would be $S_2 O_3$, which if burnt at the zincode would produce $S + SO_3$.

5. We now proceeded to apply the method of electrolysis to solve a problem of the same nature as that of the three hydrates of the phosphoric acid, viz. to determine the exact relations of the *yellow and red ferrocyanides of potassium.* It is well known that two views have been taken of the constitution of these two salts: the first represents the yellow salt as a *ferrocyanide of potassium* ($K_2, Fe Cy_3$), and the red salt as a *subsesquiferrocyanide* of potassium $K_3 + 2(Fe Cy_3)$. The second view represents the two salts as compounds of those metals with two distinct radicles, the former denominated *ferrocyanogen* ($Fe Cy_3$), the latter *ferridcyanogen* ($Fe_2 Cy_6$). The ferrocyanogen forms a dibasic acid with hydrogen ($H_2, Fe Cy_3$), the salts of which are produced by the substitution of two equivalents of the metals for the two equivalents of hydrogen; and the ferridcyanogen forms with hydrogen a tribasic acid ($H_3 + Fe_2 Cy_6$), with a similar substitution of three equivalents of the metals in their different salts. The real chemical difference, therefore, between the yellow and red ferrocyanides of potassium, consists in the latter containing half an equivalent less of potassium than the former; and so with the other salts from the two classes the metallic elements are in the proportion of 1 to $1\frac{1}{2}$.

Now Mr. PORRETT*, the discoverer of the hydroferrocyanic acid (or as he proposed to call it, the ferro-chyazic acid), long since determined that it travelled in the voltaic circuit by the electrolysis of its salts, to the zincode, the iron accompanying the cyanogen in this transfer, contrary to what might previously have been expected. The question which we now proposed to determine was, whether *ferridcyanogen* as well as *ferrocyanogen* would thus constitute a distinct anion under the directing influence of the battery.

Mr. SMEE† has already determined that the subsesquiferrocyanide of potassium may be formed from the ferrocyanide by the action of the voltaic battery; and has even proposed the process for obtaining the red salt upon a large scale. He, however, explains the change by the action of *nascent oxygen,* which he supposes to be evolved at the zincode. He observes, "that one equivalent of the yellow *ferrocyanate* is decomposed, the *free potash* travels one way, and the *hydroferrocyanic* acid the other. The oxygen unites with the hydrogen of the acid and sets ferrocyanogen at liberty; this again unites with an equivalent of the *ferrocyanuret of potassium* to form the *ferrosesquicyanuret.*" It is evident from this, that this gentleman entertains a very different notion of the steps of the electrolysis to that which we feel justified in supporting, and that therefore he has failed to place it in the point of view to which we propose to adhere.

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* Philosophical Transactions, 1814, p. 529.

† Philosophical Magazine, xvii. p. 196.

(*l.*) We commenced our inquiry by carefully repeating Mr. SMEE's experiment in a diaphragm cell, charged throughout with a strong solution of the *yellow ferrocyanide of potassium.* A voltameter was included in the circuit, and the power of twenty cells of the small constant battery was employed. Gas was evolved at the platinode, which was tested and found to be pure hydrogen; it was in equivalent proportion to the gases in the voltameter. No gas was at first evolved at the zincode, but the solution in that cell became gradually red, particularly at the surface. When 4 inches of hydrogen had been collected at the platinode a slight disengagement of gas commenced at the zincode, which continued, and proved to be oxygen, and was in the proportion of one-third of the gas from the platinode. After 16 cubic inches had been collected from the platinode, we stopped the experiment and examined the results.

The platinode solution was much paler than before, and was alkaline. The zincode solution was deep green and acid, and the zincode plate was covered with a slight film of Prussian blue. Crystals of the red ferrocyanide separated from the zincode solution by spontaneous evaporation, and when the evaporation was complete, a radiated mass of a purplish-brown colour was obtained: on solution a small quantity of Prussian blue remained, and the solution had lost its acid reagency. The addition of acetate of lead to the solution produced but a scanty precipitate, proving the quantity of yellow ferrocyanide remaining in it to be but small.

The explanation of these results is, we think, sufficiently obvious. Ferrocyanogen was doubtless transferred to the zincode, and potassium to the platinode, the former combined with a portion of the ferrocyanide to form the subsesquiferrocyanide; the process being accelerated by the abstraction of a portion of the potassium passing over to the platinode, where by its reaction upon the water of the solution it was converted into potassa with the evolution of hydrogen. As the process proceeded more ferrocyanogen was given off at the zincode than could be absorbed by the yellow salt; and it consequently began to react upon the water, becoming converted by the abstraction of its hydrogen into hydroferrocyanic acid, its oxygen being evolved. The acid reaction is thus accounted for, as well as the deposition of Prussian blue, from the well-known spontaneous decomposition of the acid.

(*m.*) This experiment was several times repeated with variation of the quantities, but with substantially the same results. The evolution of oxygen from the zincode was hastened by narrowing the dimensions of the electrode, which thus presented a smaller surface for the reaction of the ferrocyanogen upon the ferrocyanide. When the process was continued for a long time, yellow crystals of the ferrocyanide were formed in the platinode cell. Upon subsequent trial it was found that a strong solution of potassa produced a similar deposit, under ordinary circumstances, in a solution of the yellow salt. It will probably be objected, that although the red ferrocyanide is thus obviously formed by secondary action, yet where once formed it may be capable of decomposition as an electrolyte, in which ferridcyanogen acts as the anion. The following experiment however is decisive against such a view.

(*n.*) The diaphragm cell was charged throughout with a strong solution of *the red salt*, the purity of which had been tested. The solution was deep green by reflected light, but red by transmitted light. The power of the same constant battery was applied to it, and the platinode solution very quickly changed its colour and became yellow. When 5·75 cubic inches of hydrogen had been collected from the platinode the yellow colour was perfectly pure; the action was then stopped. The liquid at the zincode was of a very dark brown-green colour, and strongly acid, it had a pungent peculiar smell, the liquid soon became perfectly opake, and one cubic inch of oxygen was collected from the zincode. Though the colour of the two solutions in the electrode cells had undergone such marked changes, the colour of that in the intermediate cell remained unaltered. The liquid from the platinode cell yielded on evaporation tabular crystals of the yellow ferrocyanide, and when hydrate of potassa was added to the zincode solution, a yellow colour was developed.

Here then we obviously have the converse results of the last experiments; or the formation of ferrocyanide of potassium from subsesquiferrocyanide by the abstraction of half an equivalent of ferrocyanogen transferred from the platinode to the zincode.

(*o.*) Could a doubt remain with regard to the conclusion to be derived from these experiments, it must be removed by the results of the following arrangement. The zincode cell was filled with a dilute solution of potassa, and the connecting cell with the same. The platinode cell was charged with a strong solution of the red ferrocyanide. This solution previously to the commencement of the experiment gave no blue solution with perchloride of iron. The liquid in the zincode and connecting cells speedily became yellow, and after a short time the solution in the platinode cell also became yellow. All the solutions were now found to contain the yellow ferrocyanide. Thus it was quite clear that no such compound as ferridcyanogen travelled from the red salt when exposed to electrolysis, but that the red salt was converted into the yellow by the abstraction of ferrocyanogen from the platinode, which ferrocyanogen being transferred to the zincode, there formed with the potassium presented to it by electrolysis the same yellow ferrocyanide.

In order to extend further our knowledge of the electrolysis of this class of secondary compounds, the following experiments were made:—

(*p.*) A diaphragm apparatus was charged with a strong solution of *cyanide of po-*

tassium (K, Cy) in the platinode cell, and a solution of potassa in the zincode and connecting cells. The arrangement conducted well; gas was given off from both electrodes, and cyanide of potassium formed in abundance in the zincode cell. Hydrogen must therefore have been given off at the platinode by the oxidation of the potassium evolved, and oxygen at the zincode by the deoxidation of potassa under the influence of the current in the formation of the cyanide of potassium.

(*q*.) The apparatus was charged throughout with solution of cyanide of potassium, and subjected to the current. Gas was given off as before at the platinode; but at first none from the zincode. The liquid in the zincode cell gradually became of a deep brown colour, and the electrode itself was coated with a deep brown matter, which was easily washed off. In the latter part of the operation gas was also evolved in small quantity at the zincode. The solution smelled strongly of hydrocyanic acid, of which, by the proper tests, it was found to contain a considerable quantity. There can be no doubt that the brown matter which was abundantly formed was *paracyanogen,* which is soluble in the alkaline solution of the cyanide of potassium, and which must have been produced either by the spontaneous decomposition of the hydrocyanic acid, or in a way something analogous to the formation of the red ferrocyanide of potassium from the yellow by the absorption of an additional quantity of ferrocyanogen.

(*r*.) A diaphragm apparatus was charged throughout with *sulphocyanide of potassium* ($K, S_2 Cy$). Upon the first application of the current the action was brisk, but soon declined, and when 5½ cubic inches of gas had been collected from the platinode and 1½ cubic inch from the zincode it ceased. There was a copious orange-coloured deposit in the zincode cell and upon the plate which interrupted the progress of the electrolysis; no particular odour was perceptible in either of the cells. The liquid filtered from the zincode became turbid by exposure to the air, and deposited more of the yellow compound. The clear liquid was again subjected to the current, which it transmitted readily, and with the same phenomena as before. There could be little doubt that *sulphocyanogen* was the anion transferred in this experiment. This part of our subject still presents a tempting field for investigation, from which however we were for a time diverted by an important class of facts which next fell under our observation; we have however since returned to the study, and are at present engaged in researches upon the cobaltocyanides, and other double cyanides, the results of which we hope ere long to lay before the Society.

6. We were purposing to follow up the examination of the double salts by the electrolysis of other classes of these compounds, when we were stopped by the occurrence of a new order of phenomena, which it was necessary to turn aside and examine as affecting the very foundation of the process which we were employing. In our examination of the phosphates, our plan had been to transfer by electrolysis the acid of the salt placed in the platinode cell into a solution of potassa placed in the zin-

code cell for its reception, and then to determine its quantity and its properties from those of the salt which was formed by secondary combination.

The arrangement which we now made was to place the salt at the zincode with the view of passing its bases into an acid at the platinode. We commenced our experiments with the double sulphates with the view of comparing the different hydrates of the sulphuric acid with the hydrates of the phosphoric acid already examined, and throwing more light upon the results of the electrolysis of the dilute acid.

(*s.*) Some pure *sulphate of potassa and copper* ($CuO, SO_3, + KO, SO_3$) was carefully prepared, and its solution placed in the zincode and connecting cells of the diaphragm apparatus: the platinode cell was charged with dilute sulphuric acid, the current of twenty cells of the battery was transmitted through the arrangement until 48 cubic inches of hydrogen had been collected from the platinode, and 23·5 cubic inches of oxygen from the zincode (about one equivalent in grains), when the process was stopped. The platinode solution was perfectly colourless with a very slight deposit of copper upon the platinode, amounting only to 0·1 grain. It was evaporated to dryness in vapour of ammonia, and the residue was perfectly white sulphate of potassa, which weighed 21 grains. It was entirely soluble in water: and ammonia did not produce the slightest blue colour in its solution. The liquids of the zincode and connecting tubes together required 51 grains of dry carbonate of soda to neutralize the free acid. Now, it will be observed, that the sulphate of potassa was only one grain less than a quarter of an equivalent, which considering the nature of the processes by which these quantities were determined, will appear a very near approximation; and we may take the results of the electrolysis to have been as follows:—For one equivalent of force as measured by the gases evolved at the zincode and platinode, half an equivalent of oxysulphion of potassium (sulphate of potassa) was decomposed (as measured by the quarter equivalent potassium transferred), and half an equivalent of oxysulphion of hydrogen (aqueous sulphuric acid): for it will be observed, as most remarkable, that the quantity of copper transferred was perfectly insignificant.

Upon the view of the principle of electrolysis hitherto commonly admitted, viz. definite decomposition with equivalent and opposite transfer of the elements or radicles of the compound to the opposite electrodes of the battery, these results were sufficiently perplexing: but our perplexity increased as we proceeded; and it was not till after we had expended an incredible amount of labour in testing different hypotheses of various resistances and opposing forces, supposed to be developed in these complicated cases, that we thought of questioning the principles themselves. These abortive attempts we shall not, of course, obtrude upon the Society, but proceed to select such experimental evidence as may be sufficient to establish, in as concise a manner as possible, the conclusions to which we have arrived.

(*t.*) A solution of *sulphate of alumina and potassa* (alum) ($Al_2O_3, 3SO_3) + (KO, SO_3)$

was subjected to exactly the same treatment as the preceding double salt, and the results were precisely similar. 48 cubic inches of hydrogen were collected from the platinode. When ammonia was added in excess to the solution in the platinode cell no precipitate was produced, which proved the absence of alumina. Evaporated to dryness, the saline residue was ignited, and weighed 21 grains. It was sulphate of potassa, and the amount, as before, was within one grain of the quarter of an equivalent.

(*u.*) Some of the double *sulphate of magnesia and potassa* ($MgO, SO_3, + KO, SO_3$) was carefully prepared, and submitted in solution to the same treatment. After 48 cubic inches of hydrogen had been collected the platinode solution was evaporated to dryness, and left a saline residue of 36·6 grains. This was redissolved and treated with carbonate of potassa. A precipitate of carbonate of magnesia was thus obtained, which was reconverted into sulphate, and weighed 3·8 grains; this was equivalent to 0·76 grain of magnesium, to which must be added 0·24 grain recovered from the wash water by means of phosphate of ammonia, making the total quantity of magnesium which had passed over to the platinode 1·0, or about $\frac{1}{12}$th of an equivalent. Deducting the total amount of sulphate of magnesia, 4·98 grains, from the mixed sulphates, 36·6 grains, we have 31·62 as the amount of the sulphate of potassa.

Thus it appeared that the three bases, alumina, magnesia, and oxide of copper, or their metals, when in combination with sulphuric acid and potassa, refused to travel from the zincode to the platinode under the influence of the voltaic current into an acid with which they were capable of forming an immediate and soluble combination. Could it be that the same results might follow from the electrolysis of the single salts of the same acid?

(*w.*) Some pure *sesquisulphate of alumina* ($Al_2 O_3, 3SO_3$) was prepared by precipitating alum with excess of ammonia, thoroughly washing the precipitate and redissolving it in sulphuric acid, with the aid of heat. An excess of alumina was left, from which the liquid was separated by filtration. It was then evaporated till it solidified upon cooling. The mass was subjected to pressure in calico, and the dry salt dissolved in water.

The zincode and connecting cells of the diaphragm apparatus were then charged with the solution, and the platinode cell with dilute sulphuric acid. The arrangement conducted well, and in half an hour 13 cubic inches of oxygen were collected from the zincode. The process was then stopped, and on supersaturating the liquid at the platinode with ammonia, the slightest possible trace of alumina was precipitated.

Thus it again appeared that the electrolysis was carried on without the transfer of the base or its metal to the platinode.

Was the peculiar constitution of this salt as a *sesqui* compound concerned in any way in this result?

(*x*.) A salt of the same order, viz. the *sesquisulphate of iron* ($Fe_2 O_3, 3SO_3$), was prepared with great care, and its solution treated exactly in the same way as the last. It conducted well, and 13 cubic inches of oxygen were collected from the zincode in twenty-eight minutes. On neutralizing the liquid of the platinode cell with ammonia, very slight traces of sesquioxide of iron appeared. The sesquioxide of iron had therefore resisted the transfer as well as the sesquioxide of aluminum.

(*y*.) We next tried salts of the more ordinary constitution of single equivalents of acid and base. The zincode and connecting cells were charged with solution of *sulphate of copper* (CuO, SO_3), and the platinode cell with dilute sulphuric acid. The combination conducted well, 23·6 cubic inches of oxygen were collected from the zincode, and an equivalent of hydrogen from the platinode; but the platinode plate was scarcely covered with a very thin film of copper, the metal not having been transferred in any considerable quantity. Upon neutralizing the solutions on the two sides by carbonate of soda, it was found that an equivalent of sulphuric acid had travelled to the zincode. Upon reversing the arrangement, oxygen was collected as before from the zincode, and an equivalent of copper was thrown down upon the platinode, but no hydrogen was evolved.

(*z*.) The last experiments were varied by the substitution of solution of sulphate of potassa for the dilute sulphuric acid in combination with the sulphate of copper. When the copper solution was placed at the zincode, none of the metal passed over to the platinode, but a full equivalent of hydrogen was collected with alkali and acid at their respective electrodes. When the position of the two salts was reversed, the potassium travelled into the platinode cell, and was at once indicated by a precipitate of hydrated oxide of copper. The platinode plate was also covered partly with coherent copper, and partly with pulverulent metal, and only 3 cubic inches of hydrogen were collected for 71 cubic inches of mixed gases in the independent voltameter. None of the copper solution had penetrated to the zincode cell.

Thus it appeared that copper refused to exchange places with potassium in the circuit, as it had before refused to exchange with hydrogen, and so to pass from the zincode to the platinode.

(*a. a.*) *Sulphate of zinc* (ZnO, SO_3) was next subjected to the same treatment, and the results were exactly similar; the metal in all cases refusing like the copper to pass from the zincode division of the diaphragm cell to the platinode in any considerable quantity.

To ascertain whether the passage of the current from one electrolyte to another was in any way concerned in preventing the transfer of the base, we now resolved to employ *sulphate of copper* in solution *throughout* the whole arrangement, and having carefully ascertained the proportion of copper in solution, we placed 1500 grains of the liquid in each cell; metallic copper was thrown down on the platinode, and on precipitating the oxide from the liquid in the cell by potash, we found exactly the same amount of copper (taking the united quantities obtained from the oxide precipitated, and from the metal deposited) as before the experiment. An equivalent of sulphuric acid was set free at the zincode, but the quantity of the copper solution in the cell continued the same as at the commencement. Copper thus appeared to refuse to exchange with itself in electrolysis.

Sulphate of zinc afforded results exactly similar.

(*a. b.*) That the diaphragm itself did not throw any obstruction in the way of such transfer we satisfied ourselves, by varying its substance, from membranes to porous earthenware; but this was put out of all doubt in the following manner. A long siphon tube reversed was filled with a strong solution of sulphate of copper, and two strips of copper were made the electrodes of the battery; the action proceeded very slowly, but after a long time the liquid in the platinode limb of the apparatus became sensibly lighter-coloured, while that in the zincode became darker; the oxysulphion disengaged at the latter point had dissolved the copper of the zincode, which, however, had no power to pass to the platinode, to replace the metal which had there been deposited.

The preceding experiments bear closely upon an observation familiar to persons engaged in electrotyping on the large scale, viz. that the solution around the platinode becomes impoverished, and at last nearly deprived of copper.

As it appears to be thus established, that in the electrolysis of complex electrolytes, the metals which are capable of decomposing water at ordinary temperatures, or whose oxides are largely soluble in water, are susceptible of transference in the voltaic circuit from the zincode to the platinode, whilst those which are not marked by this strong affinity for oxygen remain stationary; we were anxious to ascertain to which class ammonium belongs.

(*a. c.*) The apparatus was charged with a solution of *muriate of ammonia* (NH_4 Cl) of known strength throughout; 35·5 cubic inches of hydrogen were collected from the platinode; the zincode liquid was yellow and smelt strongly of chlorine. By careful neutralization with muriatic acid, it was ascertained that an equivalent quantity of ammonia had been disengaged in the platinode cell, and by precipitation of the chlorine with nitrate of silver, from the liquid thus neutralized, we found that the solution contained the same amount of chlorine as before the experiment; the amount of ammonium in combination with it, must, therefore, have remained unchanged: it had received no addition by transfer from the zincode side. The results of the experiment were perfectly clear and decisive.

(*a. d.*) In an experiment which was made in the same manner with *microcosmic salt* (NaO, NH_4 O, HO, $P_2 O_5$), the sodium travelled to the platinode, but the whole of the ammonium remained in the zincode cell. Here a *polybasic* acid was used, and yet results similar to those with a monobasic acid obtained. We have still further evidence that the nature of the acid does not appear to be connected with this travelling of the base, from the fact, that when the double *tartrate of soda and ammonia*

$\left(\left.\begin{matrix}\mathrm{NaO}\\ \mathrm{NH_4O}\end{matrix}\right\}\mathrm{C_8\ H_4\ O_{10}}\right)$, was electrolysed, putting a solution of soda into the platinode cell, the sodium was found to have travelled, but ammonium had refused to do so, as in the other cases already mentioned.

It was thus ascertained, contrary to the anticipations which we had formed upon its extreme solubility, that ammonium is included in that class of basic compounds which refuse to travel in the voltaic circuit.

(*a. e.*) To show that a relation exists between the power of transference in the circuit, and the affinity of the oxides of the metals, for water, the results of three experiments may be taken with salts of potassa, baryta and magnesia. For one equivalent of force as measured by 71 cubic inches of mixed gases from the voltameter,

14·2 grains of potassium $=\frac{1}{3}$ equivalent were transferred from sulphate of potassa into sulphuric acid.

11·5 grains of barium $=\frac{1}{6}$ equivalent, were transferred from nitrate of baryta into a solution of the same salt.

1·0 grain of magnesium $=\frac{1}{12}$ equivalent, was transferred from sulphate of magnesia into sulphuric acid.

The experiments are not rigidly comparable together, nor must the quantities be taken as absolute determinations of the amount of each metal which travels in the circuit, but only as indicating a dependence of the transfer upon the attractive power of water or its elements.

The supposed anomalous transfer of sulphuric acid in the electrolysis of its mixture with water, the investigation of which cost so much labour upon a former occasion*, is now easily accounted for upon the hypothesis of the unequal transfer of the oxysulphion and hydrogen of the hydrate to their respective electrodes.

We were next induced to seek for some such connexion between the attraction of the different *acids* for water, and their transfer to the zincode. Our experiments had already embraced a great variety of acids, differing very much from one another in this respect, and in every case the transfer had taken place; but our attention had not yet been directed to the quantitative results.

(*a. f.*) As tungstic acid forms no definite hydrate and is insoluble in water, we selected it as an extreme test of the fact, and for this purpose prepared some pure *tungstate of soda* ($\mathrm{NaO, WO_3}$) by fusing together equivalent quantities of the acid and carbonate of soda. The product of the operation was dissolved and crystallized. A solution was made which contained one-twentieth of its weight of the salt; it was placed in a diaphragm apparatus, and was found to conduct badly. The current was transmitted for $1\frac{3}{4}$ hour, when the zincode liquid was found to be distinctly acid, owing to the formation of a soluble bitungstate, and the platinode very strongly alkaline. Upon precipitating the tungstic acid from both sides, by hydro-sulphuret of ammonia and nitric acid, it was decidedly shown that a portion of the acid had travelled to the zincode cell.

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* Second Letter, p. 222.

Neutral *chromate of potassa* (KO, CrO_3), which contains an acid forming no definite hydrate with water, furnished a perfectly analogous result; and the same thing was observed in the experiments with *arsenite of potassa*.

(*a. g.*) The carbonic acid is one of those which seems to have the least affinity for water, but it has been already shown that in the electrolysis of the carbonates of potassa, soda and ammonia, it is given off as oxy-carbion at the zincode in equivalent proportions. We now repeated the experiment. The diaphragm cell was charged throughout with *carbonate of soda* (NaO, CO_2) of definite strength, and the gas tube from the zincode cell connected with a drying apparatus, and LIEBIG's bulbs. The amount of carbonic acid was ascertained by weighing the bulbs, and by careful precipitation of the liquid in the cell by caustic ammonia and chloride of barium. By these means it was ascertained that there had been a decided transfer of the acid to the zincode, though in much less proportion than that of the sodium to the platinode. From the quantities of acid transferred in these experiments (which quantities however, as they can be considered but approximations to accuracy, we have not thought it necessary to record), it would appear that those acids which form no definite hydrates, are transferred to the zincode in smaller quantity than is the case with those from which distinct hydrates are obtainable.

(*a. h.*) We were extremely anxious to devise some means of ascertaining the phenomena of transfer in the case of simple electrolysis, but were forced to abandon the attempt after many trials, from the difficulty of procuring any substance which would answer the purpose of a permeable diaphragm, whilst it could resist the heat which is necessary to bring the chlorides, or similar binary compounds into the liquid state. We, however, ascertained that when a solution of *chloride of sodium* in water was electrolysed, the chlorine was transferred to the zincode in greater quantity than the sodium from it.

(*a. i.*) To remove the possibility of its being thought that water in these experiments conveyed the force independently of the presence of the saline bodies (a supposition hardly reconcilable with the phenomena observed where the saline solution was used throughout the apparatus), the following experiments were made. The platinode cell of the diaphragm apparatus was charged with dilute sulphuric acid, and the zincode with distilled water; one diaphragm alone was employed. The arrangement conducted so badly, that in an hour and a half, with twenty cells of the battery, only 1·5 cubic inch of hydrogen was collected from the platinode. The apparatus was then recharged and the electrodes reversed, the water being now at the platinode, and the acid at the zincode. In an hour and a half 2·8 cubic inches of hydrogen were collected from the platinode. From the imperfect conducting power evinced by water in these and other experiments, we can hardly suppose that the current, in cases where the base is not transferred, is carried by the electrolysis of this fluid, mysterious and ill-understood as its electrical relations undoubtedly are.

7. In reviewing the results which we have obtained from the preceding experiments, and the conclusions which we are entitled to draw from them, it will, we think, be admitted that many of them are of the highest interest and importance, and some of them at variance with the fundamental principles of electrolysis which have been hitherto admitted.

We have seen that in every instance, the definite action of the electric current is maintained; and its passage through a compound liquid conductor is always marked by the disengagement at the platinode of hydrogen or the metallic element, or else of a group of substances, like ammonium, constituting an equivalent compound; and the simultaneous disengagement at the zincode of the non-metallic element, or a group of substances of iso-electric powers. Of such electrolytes it may be convenient to distinguish the following classes:—

1st. An electrolyte may consist of *simple ions*, and then must be constituted of a single equivalent of a metal (or H) for its cation, and a single equivalent of a non-metallic element for its anion; as K, I; Ag, Cl; &c.; they may be termed *simple electrolytes.*

2nd. An electrolyte may consist of a *compound cation*, a single equivalent of which must take the place of a metal; and a single equivalent of a *simple non-metallic anion*, as NH_4, Cl. Organic alkalies probably form compound cations of this nature, and when their salts are electrolysed, hydrogen is always disengaged with them at the platinode, as with ammonia; these and the following we may call *complex electrolytes.*

3rd. An electrolyte may consist of a *compound anion*, a single equivalent of which would take the place of the simple non-metallic anion, with a single equivalent of a *simple cation*, a metal (or H), as H, NC_2; K, SO_4; Na, NO_6.

4th. An electrolyte may consist of a single equivalent of a *compound cation*, and a single equivalent of *a compound anion*, as NH_4, SO_4.

These four cases may be included in the term *Monobasic Electrolytes*, as a single equivalent of force (measured by the voltameter) would electrolyse single equivalents of the electrolytes.

5th. An electrolyte may also consist of *two or more equivalents of a metallic cation* or (H), or of *single equivalents of two or more metallic cations* (or H); when the *anion* must consist of a *single equivalent of a compound ion*, as (K_2 $FeCy_3$). This compound ion, in the case of an oxysalt, contains the so-called anhydrous acid in combination with as many equivalents of oxygen as there are of metallic cations (or H) in the compounds, as (Na_3, $\overline{P_2O_5, O_3}$).

In this case as many equivalents of force will be required for the electrolysis of one equivalent of the electrolyte as there are equivalents of metal (or H) in the cation. They may be denominated *Polybasic Electrolytes.*

In these compound anions and cations, it would appear that the oxygen which travels with the acid group, and the hydrogen which is evolved with the alkaline group, must be connected with the other elements whilst under the influence of the current in a manner differing from that in which the latter are combined together; for we have found that in most cases this connection is immediately dissolved upon their escape from the electric influence, whilst in some others their apparent permanent combination is only the effect of secondary action, where the oxygen is capable of forming a chemical compound of a higher degree of oxygenation, and like other secondary actions of a similar nature, is variable in its amount.

8. The disengagement of the cation and anion of an electrolyte in equivalent proportions is not always effected, as is commonly represented, by their simultaneous transfer in opposite directions to their respective electrodes, in the exact proportion of half an equivalent of each; but is sometimes brought about by the transfer of a whole equivalent of the anion to the zincode, whereby a whole equivalent of the cation is left uncombined at the platinode; or by transfer of unequivalent portions of each in opposite directions, making however together a whole equivalent of matter transferred to one electrode or the other; or speaking more correctly, *by the transfer of a quantity of matter capable of exerting one equivalent of chemical force*, so that when the anion *transferred* to the zincode exceeds half an equivalent, the cation transferred to the platinode is in an equal proportion less than half an equivalent, and *vice versâ*; the anion and cation *set free* being always in equivalent proportions. We have, however, in no case observed the transfer of a whole equivalent of the cation to the exclusion of the anion.

These facts are, we believe, irreconcilable with any of the molecular hypotheses which have hitherto been imagined to account for the phenomena of electrolysis, nor have we anything more satisfactory at present to substitute for them; we shall therefore prefer leaving them to the elucidation of further investigation, to adding one more to the already too numerous list of hasty generalizations.

II. *On the Thermal Changes accompanying Basic Substitutions.* *By* Thomas Andrews, *M.D., M.R.I.A., Professor of Chemistry in the Royal Belfast Institution. Communicated by* Michael Faraday, *D.C.L., F.R.S., &c. &c. &c.*

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In a communication made to the Royal Irish Academy, nearly three years ago, I described a series of experiments on the heat evolved during the mutual reaction of acids and bases upon one another, from which the general conclusion was deduced, that when the influence of all extraneous circumstances is eliminated, the heat is determined by the basic and not by the acid element of the combination. Nearly at the same time an important memoir was published by M. Hess on thermo-chemistry, in which an opposite result was arrived at, deduced however from a very limited number of experiments, and merely announced by its author, as a probable generalization, the accuracy of which could only be determined by further researches. The principle, as stated by M. Hess, is this, that different bases disengage the same quantity of heat in combining with the same acid*.

In the present state of chemical knowledge we cannot attempt the resolution of this problem by direct experiments on the anhydrous acids and bases, even if we adopt the hypothesis, no longer universally admitted by chemists, that the proximate constituents of neutral salts are the ordinary acids and bases. Experiments performed with the concentrated acids are not adapted to yield simple results, since the mere circumstance of dilution with water produces the evolution of large quantities of heat in the case of some acids, and none, or a very slight variation of temperature in the case of others. It is for this reason that when an alkaline solution is neutralized by the addition of an equivalent of nitric acid, the heat disengaged is very different, according to the state of concentration of the acid; while the same circumstance produces little or no effect, when the tartaric acid is employed. If we institute a further comparison between the results, it will be found that while no simple relation exists between the temperatures obtained with different acids in a concentrated state, there is a very close approximation to an equal development of heat when the same base is neutralized by any dilute acid.

In many apparently simple reactions it is difficult to ascertain with certainty all the combinations and decompositions which occur, and our thermal results become proportionally difficult to interpret. Even to deduce the heat due to the combination of an anhydrous acid and alkali from that evolved when their solutions are mixed together, is a question of very great difficulty, requiring the previous determination of many data, all of which are in few instances capable of being discovered by experiment. The liquids before mixture are, in fact, solutions of the acid and alkali in the state of hydrates, and as large quantities of heat were evolved during the formation of these hydrates, and generally also during their subsequent solution, an equal absorption of heat will take place when these combinations are destroyed. A further allowance is also required for the effect of the solution of the resulting compound. After making all these corrections it is doubtful whether the result finally obtained would not be a theoretical or imaginary number.

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* Poggendorff's Annalen, Bd. lii. 107, or Phil. Mag. v. xx. p. 1.

If we adopt the view, now generally admitted by chemists, that the hydrated acids are in reality compounds of the pure acids with water performing the functions of a base, the heat produced when a dilute acid is neutralized by a base will arise from the latter displacing an equivalent of basic water*, and the general result, before referred to, may be thus expressed. "When the same base displaces water from any of its acid combinations, the heat disengaged is nearly the same." If for basic water we substitute any base, the law will receive a very general form as follows:—

When one base displaces another from any of its neutral combinations, the heat evolved or abstracted is always the same, whatever the acid element may be, provided the bases are the same.

The following experiments were undertaken for the purpose of determining the accuracy of this principle. The base selected to displace others was the hydrate of potash, and it was always employed in a state of dilute solution. The strength of the solution was ascertained by neutralizing a determinate quantity with sulphuric acid of known strength. The required quantity was weighed in a thin brass vessel of a long cylindrical form, coated externally with copal varnish. The latter precaution effectually protected it from the action of all metallic solutions. The equivalent solution of the salt to be decomposed was contained in a thin glass jar, supported within a larger one, by means of a projecting rim. The whole was so adjusted that when the brass vessel with its contents was cautiously placed in the saline liquid it was sufficiently buoyant to float, and, at the same time, it extended through nearly the entire depth of the liquid. The weight of the two liquids taken together was 1000 grains, of which the saline solution formed about 700 grains. To bring the two liquids to the same temperature, a rapid rotatory motion was given to the inner vessel, by moving a light glass stirrer round in it. In the outer vessel a very delicate thermometer with a long cylindrical bulb was suspended. As soon as a perfect equilibrium of temperature was established between the two fluids, the position of the thermometer was carefully observed. The edge of the brass vessel was then grasped with pincers, and its contents quickly added to the saline solution. The mixture was now rapidly stirred and the new position of the thermometer noted. The brass vessel was not again introduced into the liquid after the mixture had taken place.

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* Transactions of the Royal Irish Academy, v. xix. 247.

The heat evolved, except in a few instances, did not exceed 3°; and it was so arranged that the final temperature of the liquid was from 0°·3 to 1° higher than that of the surrounding air, according to the total amount of heat. When a diminution of temperature occurred the adjustments were accordingly modified.

To this method of operating several objections will at once occur, but numerous trials have satisfied me that it gives very accurate results when the variations of temperature are not considerable. The important condition of bringing the two liquids precisely to the same temperature in a short space of time is completely attained. The principal source of error is the heating or cooling of the alkaline solution during the moment of being transferred into the outer vessel, and, if the difference between the initial temperature of the fluid and that of the air had been considerable, this would have been a serious objection to the process. The difference in question rarely exceeded 2°. As a few drops of the alkaline solution remained adhering to the interior of the vessel, an excess of 3 grains was taken, which I found to be an exact allowance for the loss. A similar portion of the saline solution adhered to the outer surface of the brass vessel, but as both liquid and salt were carried off together, the error from this cause did not in any instance amount to more than a fraction of a hundredth of a degree. The exposure to the air of the caustic solution during the few minutes occupied in equalizing the temperatures induced no sensible error.

The strength of the solution was such, that when a sulphate was employed, the entire fluid after mixture contained one per cent. of anhydrous sulphuric acid. Hence the required quantity of any salt was obtained by dividing its atomic weight by the atomic weight of sulphuric acid. The alkaline liquid contained from $\frac{1}{100}$th to $\frac{1}{300}$th of potash more than was sufficient to decompose the salt.

The thermal value in water of the bulb of the thermometer employed was 6 grains; that of the glass vessel and stirrer (the specific heat of the glass being 0·140) 68 grains; making the entire value of the vessels 74 grains. The brass vessel being removed altogether after the temperatures were adjusted is of course not included. The corresponding value of the vessels in terms of the liquid obtained is 76 grains. The temperatures found are therefore corrected for the vessels by multiplying them by 1·076.

Finally, a further correction is required for the specific heats of the solutions and precipitates obtained. But as the accurate determination of the specific heat of any substance requires great care and much time, I did not attempt to examine separately the specific heat of the product of every operation. I determined, however, very carefully the specific heats of the four principal solutions formed, and estimated the specific heats of the precipitated oxides (their weights taken in the anhydrous state) from the experiments of M. Regnault. The liquids examined were solutions (of the normal strength) of the sulphate, nitrate, and acetate of potash, and of the chloride of potassium, and their specific heats were found to be respectively 0·973, 0·975, 0·971 and 0·971*.

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* See Note at the end.

I have collected the experimental results into separate tables. The first column of each table contains the name of the salt which was decomposed; the second, its weight; the third, the change of temperature found by experiment; the fourth, the same corrected for the vessels or referred to 1000 parts of the resulting mixture; and the fifth, the same referred to 1000 parts of water.

Salts of Lime.

Salt.	Weight.	Found.	Ref. to liquid.	Ref. to water.
$CaO . NO_5$	20·6	$-\overset{\circ}{0}\cdot 34$	$-\overset{\circ}{0}\cdot 37$	$-\overset{\circ}{0}\cdot 36$
$CaO . NO_5$	20·6	−0·32	−0·35	−0·34
$CaO . S_2 O_2 . 6HO$	32·7	−0·35	−0·38	−0·37
$CaO . S_2 O_2 . 6HO$	32·7	−0·31	−0·34	−0·33
CaCl	13·9	−0·34	−0·37	−0·36
CaCl	13·9	−0·36	−0·39	−0·38
$CaO . \overline{A} . Aq$	22·2	−0·35	−0·38	−0·37
$CaO . \overline{A} . Aq$	22·2	−0·35	−0·38	−0·37

The nitrate was cautiously dried on a sand-bath; in one experiment the solution was neutral; in the other, it had a slight alkaline reaction. The chloride was dried at a low red heat, but not fused. Its solution was distinctly alkaline, as this salt undergoes slight decomposition from the gentlest ignition. Of the acetate, dried in a warm atmosphere, 22·64 grains yielded 12·70 grains carbonate of lime, from which the required quantity, as given in the table, was calculated.

The negative sign indicates that when potash displaces the base in these salts, a diminution of temperature takes place. The accordance of the results within the limits of the errors of experiment is perfect.

Salts of Magnesia.

The salts of magnesia are very imperfectly precipitated in the cold by caustic potash, and therefore the change of temperature indicated by the thermometer is only a part of that produced by the substitution of potash for magnesia. A depression of temperature occurred with these salts as with the preceding, amounting to between $0^{\circ}\cdot 10$ and $0^{\circ}\cdot 15$, in experiments made with the sulphate and chloride and an equivalent of potash. With a larger proportion of the latter, a greater depression of temperature occurred, but the substitution appeared to be still incomplete.

Salts of Barytes and Strontia.

In numerous experiments with the nitrates of barytes and strontia, and with the chlorides of barium and strontium, no change of temperature occurred. The solutions were taken so dilute that a mere cloud appeared on mixture, consisting chiefly of a trace of carbonate. It is true that we have no positive proof that decomposition occurs unless stronger solutions are employed and a precipitate formed, but the comparative insolubility of these bases renders it very probable that in all cases substitution does take place.

Salts of Soda.

Salt.	Weight.	Found.
$NaO . NO_5$	21·4	$+\overset{\circ}{0}$·14
$NaO . NO_5$	21·4	+0·13
$NaO . SO_3 . 10HO$	40·3	+0·06
$NaO . SO_3 . 10HO$	40·3	+0·07
Na Cl	14·6	+0·04
Na Cl	14·6	+0·05
$NaO . CO_2 . 10HO$	35·8	+0·07
$NaO . CO_2 . 10HO$	35·8	+0·05

Salts of Ammonia.

Salt.	Weight.	Found.	Ref. to liquid.	Ref. to water.
$AdH_2 O . SO_3 . HO$	18·74	$+\overset{\circ}{0}$·70	$+\overset{\circ}{0}$·75	+0·73
$AdH_2 O . NO_5$	19·98	+0·69	+0·74	+0·72
$AdH_2 . Cl$	13·33	+0·70	+0·75	+0·73
$AdH_2 O . C_2 O_3 . HO$	17·72	+0·70	+0·75	+0·73
$AdH_2 O . C_4 H_2 O_5 . HO$	25·24	+0·69	+0·74	+0·72

These experiments repeated with another thermometer gave the following results, all corrections being made :—sulphate, 0°·76 ; nitrate, 0°·77 ; muriate, 0°·76 ; oxalate, 0°·75, and tartrate, 0°·76. These numbers agree perfectly with one another, but their average is 0°·03 higher than the above. Before examining the thermal relations of these salts, it is necessary to ascertain that their solutions are quite neutral, as the slightest excess of acid would altogether derange the results.

I attempted to prepare a solution of the hydrocyanate of ammonia, by mixing together solutions containing an equivalent of hydrocyanic acid and an equivalent of ammonia. On decomposing this liquid by potash, an elevation of temperature occurred in different trials of 0°·87 and 0°·90, which approximates to the preceding results. The anomalies presented by the hydrocyanic acid in combining with the alkalies render this fact of some importance.

The so-called neutral phosphate and arseniate of ammonia are salts anomalous in composition, and on theoretical grounds ought to differ in thermal properties from the other ammoniacal salts. If a second equivalent of ammonia (in dilute solution) be added to a solution of the ordinary neutral salts of ammonia, no change of temperature occurs; but the same addition to the neutral phosphate produced an elevation of temperature of 0°·18. The latter salt, however, loses a part of its ammonia during evaporation with so much facility, preserving always its alkaline reaction, that I am not sure whether this is a property of the salt when of normal composition, or arose from its having lost a portion of its base before solution. When the same salt was decomposed by potash, the results were not uniform; in one experiment the heat amounted to 0°·98; in another, made with the same salt, after exposure for a very short time to a warm dry atmosphere, the heat was 1°·60; and in a third, performed with a solution of the latter previously saturated with ammonia, the thermometer rose 1°·00. If we assume the heat produced during the decomposition of potash to be 0°·99, and subtract from this 0°·18, we shall have for the heat produced by the substitution of potash for ammonia 0°·81, which is nearly the same result as before. The thermal properties of all the alkaline phosphates and arseniates are very complicated, and will require further investigation.

Salts of Manganese.

Salt.	Weight.	Found.	Ref. to liquid.	Ref. to water.
MnO. SO$_3$	18·9	+1°·00	+1°·08	+1°·04
MnO. SO$_3$	18·9	+1·00	+1·08	+1·04
MnCl.Aq	24·9	+1·00	+1·08	+1·04
MnCl.Aq	24·9	+1·01	+1·09	+1·05
MnO. $\bar{S}$.Aq	30·7	+1·11	+1·19	+1·15

The composition of the chloride and succinate was determined by converting them into sulphates. 17·05 grains of the chloride gave 12·94 grains of sulphate, and 11·24 grains of succinate gave 6·91 grains of the same, from which the above quantities were calculated. The succinate, it will be observed, produces a little more heat than the other salts. It is probable indeed that all these numbers are rather above the truth from the rapidity with which the precipitate absorbs oxygen. This produces a slight but distinct evolution of heat for some minutes after the precipitation takes place.

Proto-salts of Iron.

Salt.	Weight.	Found.	Ref. to fluid.	Ref. to water.
FeO. SO$_3$.7HO	34·5	+1°·52	+1°·64	+1°·58
FeCl . 4HO	24·6	+1·57	+1·69	+1·63
FeCl . 4HO	24·6	+1·53	+1·65	+1·59

The same observation applies to these results as to the preceding.

Salts of Zinc.

Salt.	Weight.	Found.	Ref. to liquid.	Ref. to water.
ZnO.SO$_3$	20·06	+1°·73	+1°·86	+1°·79
ZnO.SO$_3$	20·06	+1·76	+1·89	+1·82
ZnO.NO$_5$.Aq.	29·56	+1·68	+1·81	+1·74
ZnO.NO$_5$.Aq.	29·56	+1·65	+1·78	+1·71
ZnO.NO$_5$.Aq.	29·56	+1·69	+1·82	+1·76
ZnCl	16·87	+1·65	+1·78	+1·71
ZnCl	16·87	+1·68	+1·81	+1·74
ZnCl	16·87	+1·67	+1·80	+1·73
ZnBr	27·57	+1·65	+1·78	+1·71
ZnI	39·54	+1·68	+1·81	+1·74

The sulphate was rendered anhydrous by cautious ignition. The nitrate was evaporated till it became a solid mass on cooling. 20·17 grains of the hydrated salt left 6·85 grains of the oxide on ignition. The chloride was cautiously fused and weighed in a covered crucible. The bromide and iodide were dried on a hot sand-bath, but not fused. The three latter compounds are slightly decomposed by the heat required to deprive them of all moisture. Hence the increments of heat obtained with them must be a little below the truth. All the above salts of zinc were precipitated by an exact equivalent of potash, and the precipitate thus formed was found to consist of the hydrated oxide. But when the acetate of zinc is treated in the same manner, the precipitate which falls is a subsalt. The supernatant liquid still contains a portion of the salt of zinc, and the addition of more potash produces a further precipitate. For this reason, on precipitating an equivalent of this salt by an equivalent of potash, the thermometer rose only 1°·31. On attempting to effect a more complete decomposition by using a double equivalent of potash, the heat obtained was rather less; but it is doubtful whether the additional quantity of alkali effected a more perfect substitution, while the precipitate was, at the same time, to a great extent redissolved. This is an interesting example of an apparent exception to the law of equibasic heat arising from a corresponding anomaly in the chemical reaction.

Salts of Mercury.

The only salt of mercury adapted to these inquiries is the chloride. Half the usual equivalent of it (17·1 grains) and of the potash solution gave, in three experiments, 0°·90, 0°·86 and 0°·89, which, all corrections made and the final results doubled, correspond to 1°·89, 1°·81 and 1°·87. I have not been able to confirm this result by precipitating the oxide from any other salt. The bromide has too little solubility in cold water. The cyanuret is not decomposed by potash, and accordingly, no heat is produced when their solutions are mixed. That the potash has not decomposed the salt is further proved by the circumstance, that on neutralizing it with an acid, the same increment of temperature occurred as if the alkali had been in a free state. The sulphate and nitrate are both decomposed when their solutions are diluted. It has indeed been lately asserted that a solution of the neutral nitrate may be obtained by precipitating the chloride with nitrate of silver. This is a mistake, as the usual decomposition occurs in this case. In fact, the solution of the supposed neutral nitrate, instead of the acid reaction of the chloride from which it is formed, intensely reddens litmus paper. If a similar experiment be made with other metallic chlorides, capable of forming neutral nitrates, no perceptible change of reaction will be found to occur. These observations fully explain the anomalies which I formerly pointed out in the action of the dilute acids on the red oxide of mercury.

Salts of Lead.

Salt.	Weight.	Found.	Ref. to liquid.	Ref. to water.
$PbO.NO_5$	41·34	+2°·77	+2°·98	+2°·83
$PbO.NO_5$	41·34	+2·77	+2 98	+2·83
$\frac{1}{2}(PbO.NO_5)$	20·67	+1·39	+1·49	+2·90
$\frac{1}{2}(PbO.NO_5)$	20·67	+1·37	+1·47	+2·86
$\frac{1}{2}(PbO.\bar{A}.3HO)$	23·64	+1·32	+1·42	+2·77
$\frac{1}{2}(PbO.\bar{A}.3HO)$	23·64	+1·33	+1·43	+2·80

In the last four experiments half quantities were taken, but the results are all reduced to the common standard in the fifth column. After the precipitate had subsided, the clear solution above was found to be highly alkaline, capable of precipitating freely the salts of lead, and containing at the same time a small quantity of lead in solution. These facts are well known, and prove that the preceding numbers represent only a part of the heat due to the substitution of potash for the oxide of lead. Their accordance shows that the salts of lead, when similarly treated with caustic potash, give equal quantities of heat.

Salts of Copper.

Salt.	Weight.	Found.	Ref. to liquid.	Ref. to water.
$CuO.SO_3$	19·90	+2°·86	+3°·08	+2°·97
$CuO.SO_3$	19·90	+2·86	+3·08	+2·97
$CuO.NO_5.Aq$	30·53	+2·86	+3·08	+2·97
$CuO.NO_5.Aq$	30·53	+2·86	+3·08	+2·97
CuCl	16·72	+2·81	+3·02	+2·91
CuCl	16·72	+2·84	+3·05	+2·94
CuCl	16·72	+2·80	+3·01	+2·90
$CuO.\bar{A}.HO$	24·87	+3·08	+3·30	+3·18
$CuO.\bar{A}.HO$	24·87	+3·02	+3·25	+3·12
$CuO.\bar{A}.HO$	24·87	+3·06	+3·29	+3·16

The sulphate and chloride were weighed in the anhydrous state. The nitrate was taken in the state of moist crystals, and their composition determined by calcination, 8·73 grains yielding 2·83 grains oxide by calcination. The result with the acetate showing a small excess of heat, I endeavoured to discover whether it could be referred to some peculiarity in the precipitate, or in the composition of the salt. The precipitate obtained in the first experiment was collected and found to weigh 10·01 grains, or 1 per cent. more than the theoretical quantity, which, supposing an equal excess of caustic potash to have been present, could only have produced an error of 0°·03. Of the crystals employed in the last experiment, 9·40 grains being digested with nitric acid and afterwards calcined, yielded 3·74 grains oxide, which is exactly the theoretical result. It appears, therefore, that the acetate of copper, when decomposed by potash, produces about $\frac{1}{16}$th more heat than the other salts of copper.

Salts of Silver.

The nitrate is the only salt of silver I have examined, and the experiment was performed in order to ascertain the position of the oxide of silver as a thermal base. The full equivalent 42·48 grains decomposed by potash, gave 3°·88, or referred to the resulting liquid 4°·17, or to water 3°·95. Two similar experiments with half an equivalent gave nearly similar results, viz. 3°·90 and 3°·94, all corrections being made and the final results doubled to bring them to the ordinary standard.

Sesquisalts of Iron.

The bases hitherto examined being all of the form MO, it was of importance to determine how far the same principle would apply to bases of the form M_2O_3. The sesquisalts of iron appeared to be the best adapted for experiment, but it is difficult to procure them in a neutral state. The most certain method of effecting this object, is to pass a current of chlorine gas to saturation through solutions of the protosalts, expelling afterwards the excess of chlorine by heat. In this way a solution of sesquichloride may be easily procured from the protochloride, and a mixture of sesquisulphate and sesquichloride from the protosulphate. But as the resulting sesquicompounds require one half more potash for decomposition than the protocompounds from which they are derived, it was necessary, in order to preserve the usual quantity of potash, to take only two-thirds of an equivalent of the latter. Accordingly 16·40 crystallized protochloride of iron, converted into sesquichloride and decomposed by potash, gave, in different experiments, 3°·83, 3°·75 and 3°·74, which, all corrections made, correspond to 3°·97, 3°·89 and 3°·88. Of the crystallized protosulphate, 23·00 grains, treated in the same way, gave 4°·09, 4°·11 and 4°·12, corresponding to 4°·25, 4°·27 and 4°·28. These results, although not identical, present a sufficiently close approximation, particularly when the uncertainty of the original composition of the crystallized salts, and the difficulty of expelling without decomposition all the excess of chlorine, are considered. Another circumstance, whose influence it is difficult to appreciate, but which will tend to modify these results, is this, that the precipitate obtained always contains potash united by so strong an affinity to the hydrated sesquioxide that the action even of hot water produces only a partial separation. It is very probable that this may occur to a different extent with different salts, and hence may be one source of variation in the thermal effects.

On reviewing the foregoing results it will be observed, that while the effect of the substitution of potash for different bases produces thermal changes, varying from −0°·34 to +4°·28, the greatest uniformity prevails in those obtained with the salts of each separate base. It is true that in some instances slight differences do manifest themselves, but these differences, I apprehend, are in general not greater than occur in the chemical reactions. It is of course essential to a perfect uniformity of result, that exact equivalents of the salt and base should be employed, and that a complete substitution should take place. But these conditions can rarely be fulfilled. It is important, however, to remark, that, with one or two exceptions, the observed deviations are in the same direction which theory would indicate. The difficulty of obtaining most of the metallic salts in a perfectly neutral condition, and in a definite state of composition, is well known; and in the case of deliquescent compounds, a separate analysis of the specimen can rarely be employed with advantage. The variable nature of the precipitate arising from imperfect substitutions is a fertile source of divergences in the results, and the tendency to this is further increased by the necessity of performing all the experiments without the application of external heat. The formation of a subsalt produces less heat than the precipitation of the hydrated oxide, for the obvious reason that in the former case an imperfect substitution takes place. A remarkable example of this has been already cited in the action of potash on the acetate of zinc, where a great deviation from the usual development of heat is distinctly shown to depend upon the precipitate being a subsalt. The same cause, no doubt, frequently interferes with the accuracy of the result in other cases, where only a small portion of subsalt is formed. In other examples, part of the original base still remains in solution; and in others again, portions of the substituting base are carried down along with the precipitate. When we take into consideration all these sources of error, the numerous instances of perfect agreement with, as contrasted with the few examples of slight deviation from, the general law of the heat of substitution being equal for the same bases, appear to be sufficient fully to establish its accuracy.

It may be here observed that the accuracy of this principle will not be in any way affected whatever views may be adopted, as to the exact changes which occur when one base displaces another. Whether we consider the final result to arise from the simple substitution of one base into the position occupied by another, or from a series of distinct chemical changes, each producing a certain thermal effect, the general facts now established will not be the less rigorously true.

The separation of most of the bases in a solid form, will of course tend to produce heat, and as this will vary with different precipitates, the numbers for the insoluble bases cannot be exactly compared with one another. The amount of the latent heat due to precipitation is unknown, but it must be the same whenever the same precipitate is formed. The correction for this cause will, therefore, be a constant quantity for the salts of the same base, and if applied, could not affect the equality of the foregoing groups of numbers. It is important to observe, that, notwithstanding the heat due to the formation of the precipitates, a diminution of temperature occurs when potash is substituted for lime or magnesia.

On a first view this last fact appears to prove that potash is a less powerful thermal base than lime or magnesia, but a closer examination will show that it is at least premature to draw such a conclusion. It must be remembered that we are imperfectly acquainted with all the chemical changes which accompany the substitutions under consideration. We know that the substituting base existed in the state of a hydrate before mixture, and that after mixture the displaced base is also obtained in the same state. But we have no means of discovering with certainty in what state these bases exist in the solutions of their neutral combinations. If we assume that they exist in the state of hydrates, then the numbers given before will express exactly the heat arising from the chemical substitutions. But if we suppose that the potash separates from its combination with water, and the lime on the other hand unites with water during the course of the experiments, then these numbers will be the general result of a series of complicated changes. Other suppositions may be made, but we cannot prove the truth of any of them. One thing is certain, that whatever these unknown changes may be, they will be precisely similar when the bases employed are the same. Hence the foregoing experiments are sufficient to prove that with the same bases, the heat arising from basic substitutions is always the same, although the numbers may not express the entire change of temperature due to that cause.

Among the circumstances which may perhaps be supposed to influence these results, are the changes of temperature arising from the solution of the saline compounds in water,—a subject recently investigated by Mr. GRAHAM. But although it is true that a different salt remains in solution after substitution from that which was present before, yet it must be observed, that neither salt during the process assumes the solid state, and the changes of temperature in question are essentially dependent on that condition. For this reason, it appears to me that the thermal effects arising from solution are not in any way brought into action in the course of these experiments.

The same general principle will be found to include nearly all the thermal results I formerly described, as arising from the action of bases and dilute acids upon one another, and upon solutions of neutral salts. In cases where the same base (as before mentioned) displaced water from any of its combinations with the acids, the heat evolved was nearly (but not exactly) the same. On the contrary, where no basic substitution occurred, there was either none, or a very slight variation of temperature. As examples of the latter, I may refer to the absence of any variation of temperature when solutions of a neutral salt and hydrated acid, capable of combining to form an acid or double salt, are mixed. Mr. GRAHAM has indeed lately made the observation, that the formation of certain acid sulphates is attended with a diminution of temperature, but the change of temperature so produced is of small amount compared with that arising from basic substitutions. It is difficult to prove that combination actually takes place when solutions containing the proximate constituents of an acid or double salt are mixed. But, as far as I have investigated the subject, the thermal properties of the solutions thus formed are identical with those of solutions prepared by dissolving the crystallized acid or double salt in water. Thus, if we prepare solutions of crystallized binoxalate and quadroxalate of potash, and add to them exactly the quantity of potash required for neutralization, the usual heat due to the substitution of potash for water will be obtained.

I have formerly shown that there is a definite evolution of heat when solutions of the common alkaline phosphates and arseniates are mixed with a solution containing an additional equivalent of base, while no change of temperature occurs when a solution of the pyrophosphate of soda is similarly treated. In the former case, it has been shown by Mr. Graham that an atom of basic water is displaced by an atom of alkali; in the latter case, no basic water is present.

In the preceding observations it has been assumed, that if the union of two substances be attended with the evolution of a certain definite quantity of heat, their separation will be attended with the absorption of the same quantity of heat. Although this proposition in the abstract is very probable, it requires to be demonstrated by direct experiment, and it is the more important to do so, as it will furnish, if true, a means of verifying the accuracy of our results. The reactions now described enable us to test it by experiment in one particular set of cases. In fact, if we take three bases, such as potash, oxide of copper, and water, capable of displacing one another in the above order, and if we measure the changes of temperature produced when the first and second, first and third, and second and third bases displace one another, then the change of temperature arising from the first substitution should be equal to the difference between the changes of temperature produced by the two latter. A few examples will illustrate this point.

The numbers expressing the heat developed when the nitrate of water is decomposed by potash and lime are 6°·76 and 7°·20. The difference of these numbers is −0°·44, indicating that a depression of temperature to that amount ought to take place when the former base is substituted for the latter. We have before seen that the result of the direct experiment is −0°·37. In this and the following cases, the temperatures corrected only for the vessels are adopted, because I have not determined the specific heats of the metallic solutions. The error in the comparison from this circumstance is wholly insignificant.

The heat produced in two experiments in which sulphate of water was decomposed by potash was 7°·24 and 7°·22. The same compound decomposed by ammonia gave in different trials 6°·40, 6°·53 and 6°·51. The difference of the means of these numbers is +0°·74. The direct experiment gave in one experiment +0°·75, in another +0°·78.

The corresponding number which expresses the substitution of oxide of zinc for water in the sulphate of water is 5°·40, and this taken from 7°·22 leaves 1°·82 for the heat due to the displacement of oxide of zinc by potash. The direct experiment gave 1°·87.

Two experiments were made to determine the heat arising from the substitution of oxide of copper for the base in the nitrate of water. In one of these experiments the hydrated oxide was taken; in the other, the anhydrous oxide, obtained by precipitating a hot solution of the sulphate of copper by caustic potash. The results agreed closely with one another, being 3°·52 and 3°·53. Taking the mean of these numbers from 6°·76, we have 3°·23 to express the heat due to the substitution of potash for oxide of copper. The result of the direct experiment was 3°·08.

A similar comparison cannot be made with the salts of magnesia or lead, because an imperfect substitution takes place when their solutions are precipitated by potash.

If we compare in like manner the other results contained in the paper before referred to, it will be found that the differences between theory and experiment rarely exceed 0°·3,—a close approximation when the defective method of investigation formerly employed, and the great difficulty of obtaining accurate results with the insoluble bases are considered.

It may be remarked that there is no notable difference in the heat developed during the solution of the oxides of zinc and copper in the hydrous and anhydrous states, which makes it probable that the heat due to the combination of those bases with water is not considerable.

The preceding experiments appear to me to be sufficient to establish the accuracy of the general principle already stated, that when one base displaces another from any of its neutral combinations (all being taken in the state of dilute solution) the heat is always the same with the same bases, but in general different with different bases. The small deviations from this law in the case of the ordinary bases are not greater than we observe in other investigations connected with heat; and I have before pointed out many circumstances which tend to account for some of these deviations. The results obtained during the decomposition of the salts of water present more remarkable anomalies, as I have formerly shown. Of these, the greater development of heat during the neutralization of the dilute sulphuric acid by alkaline solutions deserves particular notice, and still remains unexplained. The anomalies presented by the oxide of mercury and hydrocyanic acid, I have partly traced to their source. But the other results approximate too closely to one another to leave any doubt that the same principle applies to the decomposition of the salts of water as well as to that of the salts of other bases.

I have not succeeded in connecting the thermal developments, as given by experiment, with any other property of the bases. In the following list I have arranged the bases hitherto examined in the order of the thermal results, attaching to each the number expressing the change of temperature produced when its salts are decomposed by potash.

CaO	$-\overset{\circ}{0}{\cdot}36$	ZnO	$+\overset{\circ}{1}{\cdot}74$
BaO	$0{\cdot}00$	HgO	$+1{\cdot}86$
SrO	$0{\cdot}00$	PbO	$+2{\cdot}82+$
NaO	$+0{\cdot}08$	CuO	$+3{\cdot}00$
AdH_2O	$+0{\cdot}74$	AgO	$+3{\cdot}93$
MnO	$+1{\cdot}07$	Fe_2O	$+4{\cdot}09$
FeO	$+1{\cdot}60$		

Supplementary Note on the Determination of the Specific Heats of Fluids.

The accurate determination of the specific heats of fluids is of so much importance in all inquiries connected with the heat of combination, that I have taken some pains to introduce greater simplicity and accuracy into the methods hitherto employed for that purpose. The process I am about to describe is a modification of that adopted by M. REGNAULT in his valuable researches on the specific heats of simple and compound bodies, and I am also indebted to the same accurate philosopher for a knowledge of the most important precautions to be taken in inquiries of this kind.

The general principle of the following method is to compare the increments of temperature produced by the cooling of a hot body in water and in the fluid under examination. But instead of taking, as is usually done, a ball of heated metal, whose temperature at the moment of immersion cannot be known with absolute precision, I employed a thermometer with a very large reservoir, and so adjusted that the mercury does not appear in the stem till it is heated to nearly the boiling point of water. The cylindrical reservoir is about two inches long, and half an inch in diameter. A mark is placed on the stem corresponding to 201° FAHR., which point is situated about an inch and a half from the reservoir. This instrument is easily heated by means of a very simple apparatus till the mercury rises a little above the mark.

The first step of the process is to determine accurately the thermal value of the reservoir with a small portion of the stem adjacent to it in terms of water. For this purpose, a certain weight of water is placed in a cylindrical vessel of thin brass, which is suspended within a larger vessel of tin plate. A very delicate thermometer, with a long cylindrical bulb (capable of being read with ease to $\frac{1}{50}$th part of a degree), is suspended in the water, and the whole is so arranged that the initial temperature of the fluid is about 5° below that of the surrounding air.

The observer, previously agitating with a very light glass stirrer the water in the brass vessel, reads the temperature to an assistant, who notes it down and also marks the time. The former then removes the large thermometer from the heating apparatus (the disturbing influence of which is carefully prevented by a wooden screen) and, holding it at a suitable distance from the water, watches the descent of the mercury till it reaches the mark, when he instantly immerses it. The time of immersion is again noted, and the whole is gently agitated for 3½ minutes in the fluid. The temperature of the latter having now always attained a maximum, the new position of the thermometer is observed. The final temperature is never allowed to be more than 2° higher than the air.

The corrections for the heating and cooling influence of the air are very small when all the above conditions are fulfilled. They must not, however, be neglected. The rate of heating for each degree of depression per minute was found to be 0°·01, and as from 12 to 20 seconds usually elapsed between the observation of the initial temperature and the immersion of the heated instrument, the correction for that period of the observation was easily made. It was assumed that during the minute subsequent to the immersion, the heating and cooling processes counterbalanced one another; and the correction for the last 2½ minutes was made on the hypothesis that the fluid during that period was at the final maximum. The rate of cooling was found to be about 0°·012 per minute, for each degree of excess, the fluid being kept in constant agitation.

Knowing the weight of the water, the value in terms of water of the different parts of the apparatus, the temperature gained by the water and lost by the instrument, we possess all the data necessary to calculate the thermal value of the latter in terms of water.

By repeating the same experiment with an equal bulk of the liquid whose specific heat is required, we obtain the thermal value of the same instrument in terms of the liquid. From these values the specific heat may be calculated. An equal bulk of the liquid is employed in order to have the instrument immersed in all cases to precisely the same depth, and, for a similar reason, it ought to be always introduced in a perpendicular direction into the fluid and maintained in the same position during the agitation. Before calculating the final result, it is necessary to obtain an approximate one, in order to find the thermal value of the brass vessel, &c. in terms of the liquid. In actual practice this is easily effected without involving any sensible error. If the specific heat of the liquid differ considerably from that of water, the correction for the heating and cooling influence of the air must also be modified.

The weights of the different parts of the apparatus and their value in water are as follows:—

Mercury in bulb of thermometer by which the increment of temperature was measured 300 gr. × 0·033	9·9
Glass in bulb and immersed portion of stem 24 gr. × 0·14 . . .	3·3
Glass stirrer 20 gr. × 0·14	2·8
Brass vessel 420 gr. × 0·094	39·5
Value of entire apparatus	55·5

The value of the apparatus in terms of the following solutions is 57·0 grains.

If we now make

D. The difference between 201° and the final temperature of the liquid, or the heat lost by the instrument.
e. The excess of the final temperature above the air.
I. The increment of temperature observed.
I^c. The increment corrected.
F. The weight of the fluid.
Vss. The value of the apparatus in terms of the fluid.
X. The value of the instrument in terms of fluid.

Distilled Water.

	I.	II.	III.	IV.	V.
D.	132°·0	131°·7	132°·8	132°·5	132°·8
e.	1·1	0·3	0·4	1·4	2·2
I.	6·38	6·45	6·46	6·40	6·40
I^c.	6·39	6·44	6·45	6·43	6·45
F.	1234·5	1234·5	1234·5	1234·5	1234·5
Vss.	55·5	55·5	55·5	55·5	55·5
X.	62·45	62·60	62·65	62·60	62·65

Mean value in terms of water 62·59.

Solution of Sulphate of Potash (100 parts contain 2·18 salt).

	I.	II.	III.
D.	131°·8	132°·2	132°·4
e.	1·3	1·1	1·0
I.	6·38	6·42	6·45
I^c.	6·41	6·43	6·46
F.	1264·5	1264·5	1264·5
Vss.	57·0	57·0	57·0
X.	64·27	64·28	64·48

Mean value in terms of solution 64·34.
Specific heat 0·973.

Solution of Nitrate of Potash (100 parts contain 2·53 salt).

	I.	II.	III.
D.	135°·8	135°·5	135°·7
e.	1·1	1·4	1·0
I.	6·59	6·56	6·57
I^c.	6·60	6·59	6·58
F.	1264·5	1264·5	1264·5
Vss.	57·0	57·0	57·0
X.	64·23	64·27	64·08

Mean value in terms of solution 64·19.
Specific heat 0·975.

Solution of Chloride of Potassium (100 parts contain 1·86 salt).

	I.	II.	III.	IV.
D.	132°·8	132°·4	132°·3	132°·4
e.	1·6	1·6	1·6	1·6
I.	6·45	6·43	6·42	6·43
I^c.	6·48	6·46	6·45	6·46
F.	1264·5	1264·5	1264·5	1264·5
Vss.	57·0	57·0	57·0	57·0
X.	64·48	64·48	64·43	64·48

Mean value in terms of solution 64·47.
Specific heat 0·971.

Solution of Acetate of Potash (100 parts contain 2·45 salt).

	I.	II.	III.
D.	133°·5	132°·9	133°·1
e.	1·8	2·1	1·8
I.	6·46	6·44	6·46
I^c.	6·50	6·49	6·50
F.	1264·5	1264·5	1264·5
Vss.	57·0	57·0	57·0
X.	64·34	64·53	64·54

Mean value in terms of solution 64·47.
Specific heat 0·971.

III. *A description of an extensive series of the Water Battery; with an Account of some Experiments made in order to test the relation of the Electrical and the Chemical Actions which take place before and after completion of the Voltaic Circuit.* *By* JOHN P. GASSIOT, *Esq., F.R.S.*

Received December 7, 1843,—Read January 25, 1844.

1. IN a paper, which I communicated to the Royal Society in 1839, and which was honoured by insertion in the Transactions of the following year, I described a series of experiments made with some powerful voltaic batteries, for the purpose of determining the possibility of obtaining a spark *before* the completion of the voltaic circuit. I was therein enabled to establish a few facts respecting polar tension, or rather respecting the absence of any notable degree of it in the batteries I described*; for instance, I proved that, with 320 series of Professor DANIELL's constant battery, polar tension was not evinced adequate to the striking distance of $\frac{1}{5000}$th of an inch; nor was I more successful in obtaining it with a water battery of 1024 series†, constructed by the same gentleman. I also stated that, according to the present theoretical views of the action of the voltaic battery, with the apparatus I then used, it ought to have taken place; and that, if by a still more powerful apparatus it could not be obtained, the theory must, in some way or other, be incorrect.

2. The preceding negative facts are not without their value in a scientific point of view; they show us, at least, a certain limit within which the anticipated effects could not be obtained. At the same time I could not fail to admit that they were anything but conclusive, as to the actual question of the possibility of obtaining the spark before the circuit was completed. That I am justified in calling the spark, under such circumstances, an anticipated effect, may be fairly assumed, because every electrician is aware that the terminals of a voltaic series invariably evince a certain amount of tension‡; and as spark is but a consequence of tension exalted to a maximum, it is only fair to anticipate that, by increasing the tension, it would be obtained.

3. A short time after the publication of the paper to which I have alluded, a communication reached me from my friend Mr. CROSSE, of Broomfield, Somersetshire, wherein he stated that, with 1626 cells of copper and zinc, excited with river water, he had succeeded in obtaining a spark between slips of tinfoil pasted on sealing wax. This communication I immediately forwarded for publication in the Philosophical Magazine for September 1840.

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* Philosophical Transactions, 1840, p. 184, § 10.

† Ibid. § 15.

‡ Ibid. § 14.

4. I was at that time engaged in the construction of an extensive series of the water battery; but, from the difficulties of insulation, which continually presented themselves, considerable time elapsed before the battery was in a condition to afford results, on which any dependence could be placed. Having, at length, to a certain extent, surmounted these difficulties, I have been enabled especially to study the character and action of the water battery, and through it, I may hope, of the voltaic battery generally. The results of my experiments, with a description of the apparatus used, may, I think, not be uninteresting to the electrician, particularly as they establish the fact, beyond any doubt, of not only the passing of a distinct spark before the completion of the circuit, but the practicability of continuing this action for several weeks in constant succession, and enabling us to examine, with much accuracy, the rationale of the action of this extraordinary apparatus.

5. The water battery, which I have constructed, and which I am about to describe, consists of 3520 pairs, or series of copper and zinc cylinders, each pair being placed in a separate glass vessel, well covered with a coating of lac varnish. The glass cells are placed on slips of glass, covered on both sides with a thick coating of lac; this coating being fixed by heating the glass over a gas furnace, and then covering it with the varnish. The 3520 cells, thus insulated, are placed on forty-four separate oaken boards, also covered with lac varnish, each board carrying eighty cells. The boards, or trays, slide into a wooden frame, where they are further insulated by resting on pieces of thick plate glass, similarly varnished.

6. It may at first sight appear that many of these precautions are unnecessary; in truth, had I, at the outset, expected they would have been requisite, I might probably have been deterred from attempting so troublesome and lengthened an inquiry. At first I imitated the apparatus of Mr. Crosse, already referred to (3.), the copper cylinders being made water-tight that they might themselves constitute the cells; and considering such insulation would be sufficient, I attached the cells to the boards with sealing wax, poured into holes made in the boards for the insertion of each cell. I found this arrangement answer very well for a few hundred series, but when the number was augmented, and the battery completed, the insulation was sadly deficient. This induced me to take the battery asunder, and to have distinct or separate glass vessels made for each pair. After again completing the entire series, I found the insulation was even less efficient than before; for from the glass attracting moisture from the atmosphere, as well as from the evaporation of the battery, each cell became a conductor, and scarcely any effect could be produced on the *electroscope*; in fact, it was not until I had finally adopted the arrangements I have previously described, that any approximation to a tolerable insulation could be maintained.

7. The general appearance of the battery may be seen by referring to Plate I. fig. 1, where A, A′ represent the wooden frames, in which are placed the forty-four boards containing the entire battery; B a shelf on which a galvanometer can be placed, or any other apparatus for the detection of a current or chemical action.

Fig. 4.

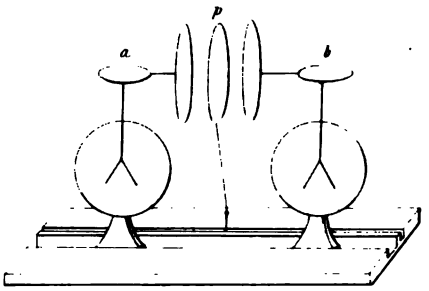


Fig. 5.

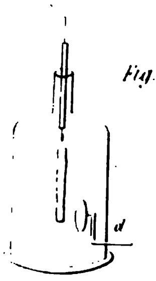


Fig. 2.

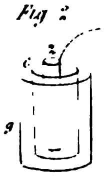


Fig. 1.

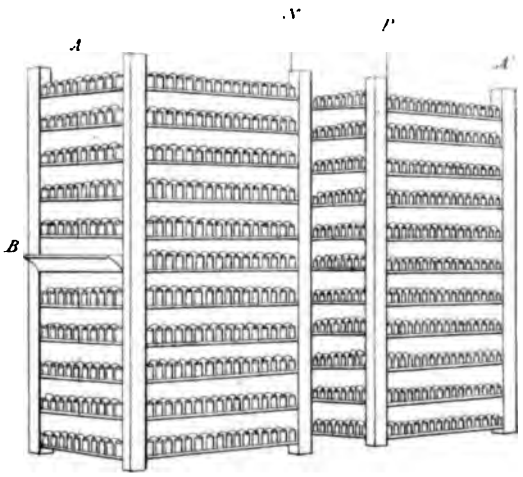


Fig. 3.

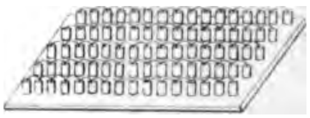


Fig. 6.

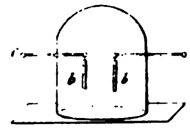


Fig. 7.

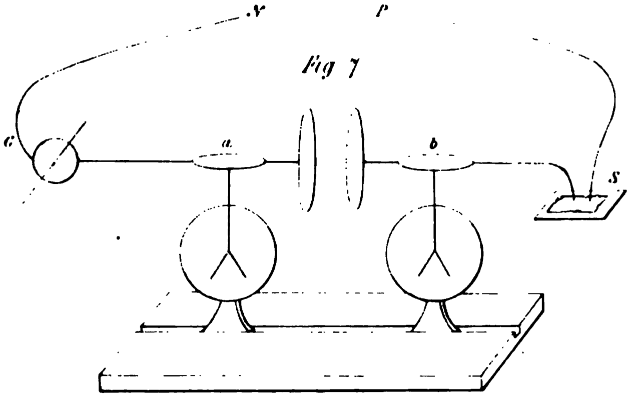
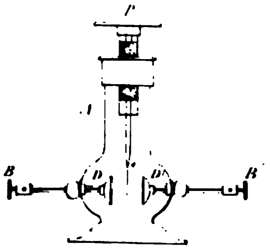


Fig. 8.



J. Basire lith.

N and P are the terminals or poles of the battery. Fig. 2 is a single cell; *g*, a glass vessel; *c*, copper; *z*, zinc. Fig. 3, one of the boards as it appears when removed from the entire series. Fig. 4, a double electroscope. Fig. 5, a HARRIS's single-leaf electroscope. Fig. 6, another electroscope, having two separately insulated gold leaves, *b b'*: in addition, I used a delicate galvanometer, and a solution of iodide of potassium for the detection of currents and of chemical action. The battery was charged, by carefully filling each cell with rain water.

8. With all the precautions I have described, the insulation of the battery was still imperfect; and, from the experience which I have gained during the construction of this apparatus, I have little hesitation in asserting, that the very nature of the water battery must prevent the experimentalist from obtaining insulation for any lengthened period, when such an extended series is employed.

9. In proceeding to describe the effects which this apparatus has presented, I must endeavour to draw a distinct line of demarcation between the *static* and the *dynamic* effects; for although these are, in a certain sense, both associated in some forms of electric development, yet as I have been enabled in a degree to isolate them here, it is my intention to regard them separately.

10. We know, from the very earliest experiments, that the extremities of a voltaic pile present opposite electrical states; it is therefore stating no new fact, to say that when one extremity of the series is connected with the ground, the other, on being connected with a gold-leaf electroscope, indicates a high degree of electric tension, and that the gold leaves diverge with considerable energy. Indeed, in the battery above described, there was little need of making connection with the ground; for, with all my precautions, I found the insulation was in a short time very imperfect, and that, by this communication with the earth, a complete circuit, to a certain extent, already existed.

11. As the *static* effects present themselves antecedently to the *dynamic*, they necessarily demand the first notice. The entire battery was connected in one series, and copper wires from the extreme cells were connected with the plates *a* and *b* of the double electroscope (fig. 4); this instantly produced a considerable and steady divergence of the gold leaves; and, on applying the usual tests, the plate *b*, connected with the copper extremity, gave signs of vitreous, and *a*, connected with the zinc, of resinous electricity. If *a* was connected with one extremity of the battery, and the other extremity was connected or not with the ground, the same general effects occurred; the divergence of the leaves corresponded with the connection, and the leaves of *b* diverged by induction; if, in this state, *b* was touched and then removed from the influence of *a*, it was found charged with the opposite electricity.

12. These inductive effects were obtained under other forms; for instance, the condensing plate (*p*), which had been removed during the preceding experiments, was opposed to the charged plate *a*. When *a* alone was connected with the battery, and *p* was touched, while under the influence of induction, and then removed,

p was found oppositely charged; as was also an insulated carrier ball, when similarly treated.

13. The plate *a* of the electroscope (fig. 4) being retained in connection with one end of the battery, a piece of very thin mica was laid on it; on this mica rested a wire W proceeding from a single-leaf electroscope (fig. 5), the disc (*d*) of which was in connection with the earth by means of a wire; with this arrangement the gold leaf was electrified by induction, and struck against the disc (*d*); glass, lac and sulphur were in turn substituted for the mica, and the same general effects resulted. The same battery connection was maintained, the electroscope (fig. 5) being disconnected. An insulated carrier ball was successively applied to the plate *a*, and an unlimited succession of charges could be carried and accumulated to another electroscope: these charges were with equal facility obtained when the *direct* connection between the battery and the earth was broken; the insulation of the battery was, however, comparatively imperfect; and I shall therefore have occasion to revert to some of these results which I afterwards obtained less in degree, but equally definite in character, from a portion of the battery detached for the purpose of more efficient insulation; for the present we need only allude to those effects, which do not absolutely involve the perfect insulations of the battery itself. When a Leyden jar, held in the hand, was subjected to the action of one end of the battery, a charge was readily accumulated, and, of course, still more favourably by means of a mica battery. When the coatings of a Leyden battery, consisting of twelve jars, with a surface of sixteen feet, were connected with the respective ends of the series, the accumulation of tension was considerable.

14. With the entire battery, the tension was so great, that the leaves of a gold-leaf electroscope diverged when that instrument was placed within two or three inches of either end of the battery, or over any of the terminal cells. Advantage was taken of this to test, whether any effect of tension could be observed when the circuit was completed; but the instant this was effected, the leaves of the electroscope as instantly collapsed, nor could I detect, either by the aid of the condenser, or otherwise, the slightest trace of tension; it, however, immediately reappeared when the circuit was again broken.

15. Thus far I have been examining the *static* effects of a moderate amount of tension, similar in kind to those which have been long familiar to the electrician, but modified so as to produce inductive effects, differing in some degree from any elsewhere recorded. My first experiment, after making every allowance for loss of electricity, or, as it would be better to express it, loss of tension through insufficient insulation, admits but of one interpretation: the interpretation itself is generally allowed, but the force of it is not, I believe, generally admitted; it is, *that the elements constituting the voltaic battery, when arranged in series, assume polar tension before the circuit is completed*; and that in the apparatus above mentioned, this tension is such *that a spark will pass before the circuit is completed.*

16. When the micrometer electrometer, described in my former paper*, was introduced between the terminal wires, sparks, through the space of $\frac{1}{50}$th of an inch, were obtained; and when the double electroscope (fig. 4) was included in the circuit, and the discs *a* and *b* were approximated, an uninterrupted succession of sparks would pass between the discs. These effects, which I have repeatedly shown to many friends, are most brilliant. On one occasion they were continued uninterruptedly day and night for upwards of five weeks; and although some months have now elapsed since this battery was completed, it still exhibits the same effects.

17. When the experimenter was standing on the ground, and consequently, as has been already explained, in actual, although imperfect connection, with the battery, he could draw sparks from either terminal. We shall, in the sequel, be enabled to trace, with more precision, the rise of this tension; for the present, we are only concerned in establishing its existence, and thereby proving the first fact, that *tension* or *electro-static effects precede, and are independent of, the completion of the voltaic circuit.*

18. Hitherto we have not obtained any insight into the condition of the *dynamic* effects under such circumstances of antecedent tension. For testing the presence of what is usually termed the current, or in other words, obtaining the means of observing the electro-dynamic effects, I used the instrument which is best suited for examining such phenomena, and which invariably attests the instant completion of a voltaic circuit. An exceedingly delicate galvanometer was introduced at B (see fig. 1), and the two condensing plates *a* and *b* of the double electroscope (fig. 4) were respectively attached by wires to the terminals N and P of the battery, fig. 1. If great care was taken not to make any connection with the ground, the party manipulating being himself well insulated on shell-lac, no action could be perceived on the needle in the galvanometer, although the gold leaves of the electroscope immediately diverged to a very considerable extent.

19. This experiment was, however, of too much importance to be passed over without adopting every means of making it unexceptionable. Two trays from the battery, being a series of 160 cells, were removed and insulated, by being supported on stout varnished glass pillars twelve inches high; the whole being placed upon an Arnott's stove in which a fire had been kept burning for several hours. The galvanometer was interposed between the zinc terminal of one tray and the copper terminal of the other; and the extremities of this reduced series were arranged so as to exhibit the same effects of electric tension which we have seen in the entire series; but not the slightest indication of dynamic action could be detected by the galvanometer. The action of the instrument I used could not be in fault; and some idea may be conceived of its extreme delicacy, when I state that, with one cell of the gas battery† I have obtained a steady deflection, whilst a resistance of twelve miles of thin copper wire was interposed in the circuit; when the electroscope (fig. 6) was used, *c c'* being respectively connected with N and P of battery, the gold leaves *b b'*, were attracted;

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* Philosophical Transactions, 1840, p. 184, § 12.

† Ibid. 1843.

and the moment they touched each other, the needle of the galvanometer was deflected.

20. The best definition that occurs to me of a current is that given by **Faraday** in his Third Series of Experimental Researches[*]. "By current I mean anything progressive, whether it be a fluid of electricity, or two fluids moving in opposite directions, or merely vibrations; or, speaking still more generally, progressive forces;" and in juxtaposition to this, he says[†], "If the magnetic effects depend upon a current, then it is evident they could not be produced in any degree before the circuit was complete, because prior to that no current could exist." Now it is manifest that, in the experiments already mentioned, the voltaic elements have the power of exhibiting electric effects at either, and both ends or terminals, before any progression or actual perceptible force takes place in the course of the series; in other words, that *static* effects exist before or independently of currents, but that these effects cease immediately on currents being developed.

21. But, in an inquiry like this, we must examine more closely the actual chemical action; for it involves much of the source of controversy between the contact and chemical theories; and I was naturally anxious to discover whether simultaneously with these *static* effects, or perhaps antecedently to them, *any chemical action took place in the cells of the battery*; and if so, to what amount.

22. **Faraday**[‡], in the course of that branch of his experimental researches which introduced into notice the voltameter, established the most accurate means of measuring the amount of chemical action in the battery cells, by the equivalent amount of chemical decomposition exhibited in that instrument; he has also directed our attention to the fact, that this amount of electro-chemical decomposition depends essentially on the current as denoted by the galvanometer. There was every reason, with these facts before us, to expect that the battery, which did not produce a current, would not evince any degree of chemical decomposition. Recourse was, however, had to the test of experiment; and, instead of introducing the galvanometer, I substituted for it a small piece of bibulous paper, saturated with a solution of iodide of potassium; the gold leaves of the electroscope diverged as before, but, however long the duration of action, not the least indication of the liberation of iodine was perceptible. The inference I make from this is, that no definite chemical action took place in any cell of the battery, and consequently that the *electric effects* above shown, and which are termed *static* effects, take place *before* or *independently of the actual development of the chemical effects*.

23. I am aware that, in some form or other, this fact has been acknowledged by the most strenuous advocates of the chemical theory. **Becquerel**[§] thus adverts to it:—"We must conclude, from all the electrical phenomena, that, in almost all cases, a chemical action has taken place; and hence we are led to believe that the latter is the cause which exercises the greatest degree of influence over their production; nevertheless,

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[*] Experimental Researches, § 283. [†] § 282. [‡] § 510. [§] Traité de l'Elect., vol. ii. p. 145; vol. v. p. 3.

in the present condition of science, we must not yet abandon VOLTA's theory, since it may very readily happen, that, at the contact of two bodies, a disengagement of electricity may take place, resulting from a commencement of chemical action between these bodies."

DE LA RIVE[*], who has laboured perhaps more than any of the continental philosophers in advocating the chemical origin of voltaic electricity, cannot but admit some such similar qualification, as may be seen from the following extract from one of his papers:—"The two theories between which philosophers are divided with respect to the origin of voltaic electricity, are still the subject of lively controversy; when we are adverting to the pile itself and to hydro-electric currents, we cannot deny the superiority of the chemical theory; the recent labours of FARADAY have, moreover, added powerful arguments in favour of this theory; but it must be acknowledged that it is not easy to defend it when we advert to electricity of tension developed in the contact of two heterogeneous bodies, especially if the two bodies are solid."

FARADAY[†], who has recently instituted a series of elaborate researches in support of the chemical theory, writes thus of it:—"The theory assumes that the particles of the di-electric (now an electrolyte) are, in the first instance, brought by ordinary induction into a polarized state, and raised to a certain degree of tension or intensity before discharge commences, the inductive state being in fact a *necessary preliminary* to discharge." Again, "One point is, that different electrolytes or di-electrics require different initial intensities for their decomposition. This may depend upon the degree of polarization which the particles require before electrolytic discharge commences[‡]."

GROVE[§], in a recent communication to the Royal Society, in allusion to the action of the gas battery, says, "If, indeed, the contact theory assume contact as the efficient cause of voltaic action, but admit that this can only be circulated by chemical action, I see little difference, save in the mere hypothetical expression, between the contact and chemical theories; any conclusion which would flow from the one would likewise be deducible from the other; there is no observed sequence of time in the phenomena, the contact or completion of the circuit and the electrolytical action are synchronous. If this be the view of contact theorists, the rival theories are mere disputes about terms. If, however, the contact theory connects with the term *contact* an idea of force which does or may produce a voltaic current independently of chemical action, a force without consumption, I cannot but regard it as inconsistent with the whole tenor of voltaic facts and general experience."

24. I shall have occasion to revert to the gas battery, the action of which is fully described in the paper from which I have taken the preceding quotation; but the action we are now examining is not that arising from *contact or completion of the circuit,* but that which is caused by contact in the arrangement of a progressive

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[*] Archives de l'Electricité, vol. i. p. 619.

[†] Experimental Researches, § 1345.

[‡] Ibid. § 1354.

[§] Philosophical Transactions, 1843.

series of the elements of a voltaic battery *previous* to the circuit being completed; such progressive arrangement being indispensable for the production of the effects we are now examining, or the production of certain forces in a given direction. A mere heterogeneous assemblage of the elements will not produce the effects; on the contrary, any alteration in the regular series produces a corresponding reduction of force, and any number of batteries arranged—copper, liquid, zinc,—will exactly neutralize the action of a similar number arranged,—zinc, liquid, copper.

25. The question I am now examining is, however, not whether contact produces current, but whether it produces electric development, and whether that development is accompanied by any chemical action; and this necessarily involves the question, whether the effects of current, or those usually called voltaic, have the same efficient cause as the electro-static. That certain effects can be produced independently of any *apparent* chemical action, is not merely proved by experiment with the water battery, but it is further confirmed by many unexceptionable experiments; among those for which I may particularly claim attention, are those of M. PECLET, who in describing them says, "I have only had in view static electricity developed by contact, I have not troubled myself about currents when the circuit is closed*."

26. The examination of M. PECLET's experiments, the investigation of the action of the voltaic series generally, and more particularly of the water battery, seem to lead to the inference that elective affinity is greatly concerned in the *antecedent* action, of which chemical combinations, when the circuit is closed, are the *consequence.* I might quote the particular experiments of M. PECLET as an evidence of static effects having been obtained without any apparent chemical combination; but, without attempting to follow out what may, perhaps, somewhat fairly, be assumed as hypothetical cases, viz. those in which tension does not appear to terminate in chemical action, *let us trace the process by which tension rises in an insulated pile, and the still further process necessary to establish a current.*

27. Two trays of the battery were carefully insulated as before (19.): if in this state one of the piles is touched by the hand, its electric tension is apparently destroyed, the leaves of the electroscope in connection collapsing; whilst those of an electroscope attached to the other terminal obtain their extreme divergence. If this battery be now left to itself, the end which has been touched regains a certain amount of tension, and the leaves of the other electroscope collapse in proportion: generally, the means of raising the tension of one extremity of the battery is to touch the other. I do not mean to assert that the tension of the end which was touched is entirely destroyed, but certainly with 160 series, for the space of several seconds, I could not with the most delicate gold-leaf electroscope obtain the slightest indication of it.

28. MARIANINI went through a series of experiments, in which he found that in no case was tension actually destroyed; but that it fell in proportion to the duration of the time during which the circuit had been completed. My object now was not, however,

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* Archives de l'Electricité, vol. i. p. 622.

to complete the circuit; for I wished to test an intermediate stage between actual insulation and actual completion of circuit, in order to discover the character of the discharges effected by touching the respective terminals, or rather their influence over the state of tension, into which the whole series was thrown. I wished, for instance, to discover whether the discharge I effected, threw the elements of the battery *back*, into the normal condition which prevailed antecedent to the discharge; or whether it threw them *forward* by completing the act of chemical combination, the preparatory state of which already existed; whether, for instance, mere discharge, either by the earth or by completion of the circuit, for an instant, is one small fraction of a current; and, if so, whether a current is not really a collection of discharges of electricity of tension.

29. For this purpose the following experiments were made: a copper wire attached to N of the battery was connected with the galvanometer, and this with the plate *a* of the double electroscope, fig. 4. A platinum wire was attached to P of the battery, the end of which rested on a piece of bibulous paper saturated with a solution of iodide of potassium: another platinum wire, also resting on the paper, was connected with the other plate *b* of the electroscope; by the mechanical arrangement of this instrument, the plates could be approximated or separated as required. Fig. 7 shows the arrangement; N and P, the terminals of the battery; G, the galvanometer; *a* and *b*, the plates of the electroscope; S, solution of iodide of potassium.

30. When the plates *a* and *b* were approximated so as to permit sparks to pass at intervals of about a second, a *tremulous* motion was imparted to the needle; but when they were brought so nearly in contact as to permit the discharges to take place in quick succession, the needle was *steadily* deflected, and iodine freely evolved; proving that chemical action was occurring in each cell, and that the current is a collection or an accumulation of discharges of electricity of tension; for although the circuit was completed by distinct and separate discharges, still the deflection of the needle was as steady as if the discs had been in actual metallic contact.

31. The discs *a* and *b* were then separated to the distance of about an inch; a piece of tinfoil was suspended by means of a thread of white silk; the tinfoil vibrated between the plates, but no effect could be produced on iodide of potassium or on the galvanometer.

32. I have already alluded to the extreme difficulty I experienced in effecting perfect insulation. I was anxious to ascertain whether this insulation, and at the same time a high state of intensity, could be obtained, and whether, in such a state, any evidence of chemical action could be detected when one end of the battery was in connection with the ground. After many trials, I succeeded in insulating 320 cells; and so efficient was even this reduced number in point of intensity, that sparks could be obtained by means of the micrometer electrometer through a space of $\frac{1}{1000}$th of an inch. The ends of two platinum wires were then fixed so as to rest on a piece of bibulous paper saturated with a solution of iodide of potassium. One of the

wires was connected at one time with the copper, and at another time with the zinc terminal of the battery; while the wire attached to the other extremity was connected with the earth. This arrangement being continued for several hours, and the paper kept constantly moist, not the slightest evidence of any evolution of iodine could be detected, until by a momentary contact made with the further extremity of the battery and the ground, either by a wire, or by touching it with the hand, the circuit was completed. Here we have a voltaic battery the intensity of which is sufficient to elicit a *spark* between its terminals before the circuit is completed, but in which antecedent thereto, the slightest chemical action is not appreciable; and this when one end is in connection with the earth, and consequently having the intensity exalted to a maximum short of actual discharge.

33. I am aware of the many forms the contact theory has assumed since Volta first propounded it; nor can we lose sight of the many errors which his successors have committed in attempting to follow out their favourite views of metallic contact and electro-motive forces. I am indebted for much information on this point to the kindness and industry of Mr. C. V. Walker, who has occupied much time in procuring me references to the researches of those electricians already alluded to, as also to a long list of others whose names adorn the pages of science. I could easily have added to those I have named, by referring to the experiments of many other authors who consider that their favourite theory of contact has been fully established. It is not, however, my object to advert to these speculations: we have before us certain facts connected with the action of the voltaic battery; first *contact*, or successive juxtaposition, and simultaneously with it, effects of *tension*; then the completion of the circuit, and simultaneously with it, *development of chemical action* and *current*; but in all these cases contact is first in order, developing tension. Becquerel describes it by stating, "When two bodies are in contact the affinities commence exercising their action before combination takes place." M. De la Rive, "The electricity of tension developed by contact of heterogeneous bodies." Faraday, "That the particles of the electrolyte are brought into a polarized state, and raised to a certain degree of tension, before discharge takes place:" but I am not aware that there are any *experimental* facts to prove whether this tension in the voltaic battery, which itself is of an opposite character at each terminal, and, as we have seen, can be exalted so as to produce discharges in the form of sparks for many weeks' constant duration (16.), is due to the chemical constituents of the battery, or to mere contact of dissimilar bodies, without reference to their chemical affinities. I was therefore most anxious to see whether some experiment could not be devised, which would test the action in a satisfactory manner, and for this purpose I availed myself of an extended series of Grove's gas battery, described by him in a paper already alluded to (23.)*.

34. The elements used in this form of the voltaic battery consist of two gases and one metal; with fifty series charged with oxygen and hydrogen, it is stated that the

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* Philosophical Transactions, 1843.

gold-leaf electroscope was notably affected. The instrument used by Mr. Grove, whose original experiments I had the pleasure of witnessing in the laboratory of the London Institution, was the same as is represented in fig. 6. Nothing can be more decisive than that the *static* effects of the voltaic battery are not due to the contact of dissimilar *metals*; as in this arrangement, only one metal, platinum, is used; but this battery, whose action is, in itself, so purely chemical, presents to us a full corroboration of the *static effects preceding the development of chemical action.*

35. A series of forty cells, the same as are described in Mr. Grove's paper[*], were charged with oxygen and hydrogen; these sensibly affected the gold-leaf electroscope, fig. 3. This arrangement was kept charged for upwards of three months. No decrease in the gas of the oxygen tubes could be detected. Whenever the terminals were tested by the electroscope, they invariably exhibited the usual signs of tension; but not the slightest chemical or dynamic effect could be obtained until the entire circuit was completed.

36. Here we have a battery, the active elements of which are two gases, which, with a closed circuit, immediately enter into active chemical combination; remaining for upwards of three months in such a state of tension as at all times to affect the leaves of an electroscope; but in which no amount of chemical action could be detected whilst the circuit remained open.

37. It now became a matter of some interest to ascertain, *first*, the minimum amount of series with which the gas battery charged with oxygen and hydrogen would exhibit static effects; and, *secondly*, whether, when it was charged with gases which do not enter into chemical combination, *any* signs of tension could be elicited.

38. By careful arrangement I obtained an attraction in the gold leaves of the electroscope (fig. 6) with a series of nine pairs; with twelve or fourteen, the effects are very distinct, and required no very delicate manipulation. The series of forty pairs was then charged with oxygen and nitrogen; at first the electroscope was affected, and chemical action as well as dynamic effects were obtained with the closed circuit; these, however, were evidently due to impurities in the nitrogen (this gas was obtained by burning phosphorus in common air; the oxygen by electrolysis): after keeping the circuit closed for two days, these effects ceased, when not the slightest static, chemical or dynamic actions could be detected; the volumes of the gases remaining perfectly stationary, whether the circuit was closed or open.

39. From the preceding experiments we learn that, when the gases used in this battery are oxygen and hydrogen (which will from their affinity for each other enter into chemical combination), a series of ten or twelve is sufficient to develope static effects; but that, when charged with gases which have not this power, viz. oxygen and nitrogen, even a series of forty does not affect the electroscope.

40. The advantage of using oxygen and hydrogen is, that although the hydrogen is slightly absorbed by local action with the atmospheric air in the solution, action

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[*] Philosophical Transactions, 1843, plate 5. fig. 1.

does not take place in the oxygen tubes until electrolysis commences; and we have thus the most correct means of defining our results.

41. With hydrogen and chlorine, signs of tension were obtained with a series of six pairs of cells.

42. With chlorine in a single tube, and amalgamated zinc as the positive element, a combination by which, as GROVE has shown*, one pair will decompose water, a series of two pairs affected the electroscope.

43. Having thus elicited that for the purpose of obtaining static effects with a gas battery, it is indispensable that the two gases employed be capable of entering into chemical combination with each other, and having found that the higher the state of their mutual chemical affinities, the less was the number of series required to produce static effects, my attention naturally reverted to the older forms of the voltaic battery. I allude to those having two metallic elements excited by acid solutions.

44. Ten of the glass cells of the water battery (5.) were filled with dilute sulphuric acid. In each cell I placed a small porous earthenware vessel, also filled with the same solution. The metallic elements in this arrangement were amalgamated zinc and platinum; the latter being placed in the porous vessels, each cell was carefully insulated. This arrangement affected the leaves of the electroscope (fig. 6), while it required sixteen series of the water battery (5.) to produce the same effect.

45. The dilute acid was then removed from the porous vessels, and these were refilled with strong nitric acid, forming the well-known nitric acid battery of GROVE. Three series of this arrangement affected the electroscope, and with the assistance of a ZAMBONI's pile, *distinct signs of tension could be elicited from a single pair*; the platinum showing vitreous and the zinc resinous electricity.

From the preceding experiments it appears, that to obtain evidence of tension, the principal requisite is good insulation, and that this condition being fulfilled, the most energetic chemical battery will exhibit signs of tension before the completion of the circuit with a smaller series than that which is merely excited with rain water (44. 45.).

Conclusion.

The deductions which I make from the experiments described in this paper are as follows:—

1st. That the elements constituting the voltaic battery assume polar tension before the circuit is complete (10. 11. 15.) even in a single cell (45.); and that the existence of this polar state is demonstrated by the action on the electroscope being different at each terminal of the battery.

2nd. That this tension, when exalted by a series of pairs, is such, that a succession of sparks will pass between the terminals of the battery before their actual contact (16. 32.).

3rd. That these static effects precede, and are independent of, the completion of the voltaic circuit (10. 11. 17.), as well as of any *perceptible* development of chemical or dynamic action (18. 19.).

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* Philosophical Transactions, 1843, p. 103, Note.

4th. That when the circuit is completed, whether by actual contact of the terminals, or merely by approximating them, so as to allow a succession of sparks, the dynamic effects on the galvanometer are the same (30.); each producing a steady deflection of the needle; consequently that the current, even when the circuit is closed, may be regarded as a series of discharges of electricity of tension, succeeding each other with infinite rapidity.

5th. That the rise of tension in a battery (the chemical affinities of its elements being feeble, as in the water battery) occupies a measurable portion of time (27.).

6th. That to produce *static* effects in the voltaic battery, it is indispensable that the elements should be such as can combine by their chemical affinities (34. 35.), that the higher those chemical affinities are exalted, the less is the number of elements required to exhibit the effects of tension (38. 39. 41. 42. 44 and 45.), and consequently, that the *static* effects elicited from a voltaic series are direct evidence of the first step towards chemical combination or dynamic action.

The chemical effects, when obtained in the generality of the experiments described in this communication, are of course feeble; but they are precisely the same in character as those exhibited by the more powerful voltaic combinations; and it may fairly be concluded that the rationale of each is the same, and that they only differ in the degree of action.

Received April 12, 1844.

Note.—I have recently constructed an instrument, by means of which the tension in a single series of the voltaic battery can with facility be tested without the aid of Zamboni's pile. Fig. 8 represents the electroscope, in the construction of which I was in a great measure indebted to an apparatus described by Dr. Hare[*]. A is a glass vessel, the stem of which is well-coated with lac; B, B′, two copper wires passing through glass tubes and corks; D, D′, gilt discs, each about two inches diameter, attached to the wires; P, a copper plate with a wire passing through a glass tube; to the end of the wire is attached a *narrow* strip of gold leaf, L. The discs must be adjusted with care, so as to allow the leaf to be equidistant from each. If B is connected by a wire attached to the platinum, and B′ by another wire attached to the zinc of a single cell of the nitric acid battery, insulated on a plate of lac, and an ex-

[*] Silliman's Journal, vol. xxv.

cited glass rod is approximated very gradually towards the plate P, the gold leaf will be attracted to B′, or the disc attached to the zinc; and if excited resin is approximated in a similar manner, the leaf is then attracted to B, or the disc attached to the platinum. By means of this instrument, my friend, the Rev. CHARLES PRITCHARD, obtained signs of tension in a single cell excited by dilute sulphuric acid with platinum and zinc. This experiment I subsequently verified, and obtained similar results with single cells of other usual arrangements of the voltaic battery; but in all the experiments I made, the higher the chemical affinities of the elements used, the greater was the development of the evidence of tension.

March 1844.

IV. *On the Existence of Phosphoric Acid in Rocks of Igneous Origin.* *By* GEORGE FOWNES, *Ph. D., Chemical Lecturer in the Middlesex Hospital Medical School. Communicated by* THOMAS GRAHAM, *Esq., F.R.S., &c. &c.*

Received April 17,—Read April 25, 1844.

THE important although obscure functions attributed to the elementary body phosphorus, both in the vegetable and in the animal kingdoms, and the well-known fact that rocks of nearly every description afford on disintegration soils more or less capable of supporting the life of plants, and from which consequently phosphoric acid cannot possibly be absent, seemed to render a search for that substance in rocks of igneous origin generally very desirable, because if there found, an easy and satisfactory explanation of the origin and first source of the element in question would be given. As I am not aware that any direct researches on this subject have yet been made, or at least placed on record, I venture to submit to the notice of the Royal Society the results of a few experiments made by myself, which, so far as they go, resolve the question in the affirmative.

The first substance tried was the fine white porcelain-clay of Dartmoor, Devon, the result of the disintegration of the felspar of the granite of that district. This is one of the chief components of porcelain and of the finer kinds of English earthenware, and was found on analysis to correspond very closely in composition with that of the material employed in the manufacture of the Sèvres porcelain. It was thought that phosphoric acid, if present, would be in combination with a portion of the alumina; and as the phosphate of that earth is readily soluble in dilute mineral acids, while the silicate offers great resistance to these agents, mere digestion with acid would suffice to extract the whole, or the greater part of the phosphate, which could be afterwards precipitated by an alkali, and examined.

With this view, 1000 grains of the clay were boiled during several hours in a flask with a quantity of pure dilute hydrochloric acid; a large bulk of distilled water was then added, and the whole allowed to rest until perfectly clear. The acid liquid was then carefully decanted from the undissolved clay, evaporated in a porcelain basin to a small bulk, and precipitated by a slight excess of pure ammonia. The scanty, reddish precipitate obtained, which consisted chiefly of alumina and oxide of iron, was collected upon a little filter, thoroughly washed with distilled water, dried, and ignited. It was next reduced to fine powder, and mixed with an equal weight of pure silica in a finely-divided state, and six times as much anhydrous carbonate of soda. This mixture was heated to fusion in a platinum crucible. When cold, the melted mass was acted upon by boiling water, and the soluble and highly alkaline portion separated by a filter from the insoluble silicate of alumina. The solution was mixed with excess of nitric acid, evaporated to dryness, water added, and the product filtered. The liquid thus obtained was divided into two portions; one of these was carefully neutralized by a little ammonia, and mixed with a few drops of solution of nitrate of silver; a distinct yellow precipitate appeared, which was freely soluble in dilute nitric and in acetic acids. The second portion was mixed with excess of ammonia and some hydrochlorate of ammonia, and a few drops of solution of sulphate of magnesia added. After a short interval, a crystalline, granular, white precipitate, the ammonio-magnesian phosphate, made its appearance, which increased in quantity by agitation.

This experiment, which demonstrates the presence of a small quantity of phosphoric acid in the clay, in a most unequivocal manner, was several times repeated with a like result. The purity of the acids, carbonate of soda, and other materials employed, were rigorously tested, and filtration through paper of the original acid liquid purposely avoided, lest a trace of earthy phosphate should have been dissolved from the paper.

The porcelain-clay is extracted from the disintegrated granite by mere washing with water, and subsidence, and the water of the district in which it is found is, in all probability, exceedingly pure. It was thought worth while, however, to examine in the same manner the decomposed rock which had not been subjected to any artificial treatment, and a specimen taken by myself from the quarry was chosen for the purpose. The result showed the presence of phosphoric acid as in the clay, and apparently to about the same extent, allowance being made for the quartz-grains, mica, &c.

In the examination of unaltered felspar, I failed, unfortunately, in getting a conclusive result. The mineral, although reduced to very fine powder by trituration in a mortar of Swedish porphyry, was found to be so hard and dense as to resist completely the action of the acid at a boiling temperature. An insignificant quantity of oxide of iron was dissolved out, in which no phosphoric acid could be detected. 200 grains of the powdered felspar were then fused with a large excess of carbonate of soda; the mass was treated with water, filtered, the solution supersaturated with nitric acid, and evaporated to dryness; water was poured upon the residue, and the whole placed upon a filter. The solution was then examined, as before, for phosphoric acid, but with an indistinct and doubtful result. Too small a quantity of the felspar had been used, and the mass of nitrate of soda present interfered too seriously with the action of the tests to render their evidence of any value. A far better mode of investigation would be, to act upon the powdered mineral with hydrofluoric acid, in the manner recommended by some analysts in the examination of natural silicates containing an alkali; not being, however, in possession of the necessary platinum vessels, I was obliged to abandon the attempt.

Other substances were then tried with very decisive results. The method of proceeding adopted was very much the same as that already described. The minerals were very finely powdered in the porphyry mortar and boiled, as before, with dilute hydrochloric acid. All were much more readily attacked than the porcelain-clay, and yielded solutions containing a large quantity of alumina and oxide of iron. The liquid was separated from the insoluble part by decantation, evaporated nearly to dryness, water added, and then an excess of ammonia. The copious, bulky precipitates obtained were washed and digested in dilute acetic acid, which has the property of dissolving with great facility both oxide of iron and alumina, while it leaves untouched the phosphates of those bases. The undissolved residue was dried, ignited, fused with silica and carbonate of soda, and the product examined in the manner already described. The addition of silica is indispensable to the retention of the whole of the alumina in an insoluble condition. Phosphate of alumina is not decomposed by carbonate of soda by fusion, or only partially, and is besides soluble in an aqueous solution of that salt.

The results of the examination may be thus briefly stated:—

Dark grey vesicular lava from the Rhine, used at Cologne as a building-stone, being exceedingly strong and durable.—Enough phosphate of soda was extracted from 1000 grains of this substance to exhibit the yellow phosphate of silver, and the phosphate of magnesia and ammonia upon a large scale. The phosphoric acid might be said to be here *very abundant*, that is, comparatively speaking. No attempt was, however, made to estimate it quantitatively, as the operation is attended with great difficulty, and the result of doubtful value from the unavoidable errors of experiment bearing too large a proportion to the quantity of the substance.

White trachyte of the Drachenfels, near Bonn, on the Rhine.—This rock is apparently as rich in phosphoric acid as the preceding; nothing could be more distinct and satisfactory than the indications of the reagents.

Dark red, spongy, scoriaceous lava from Vesuvius.—This was tried in the same manner, and yielded *abundance* of phosphoric acid.

Compact, dark green basalt, or toadstone, *from Cavedale, Derbyshire.*—This substance was very tough, and difficult to powder. Enough phosphate of soda was, however, extracted from 750 grains of the rock to exhibit very unequivocally the characteristic tests described.

Dark blackish-green, extremely strong basalt from the neighbourhood of Dudley, termed *Rowley-ragg*, gave a very similar result. Phosphoric acid is not so plentiful in these substances as in the lava, although its presence is easily rendered evident.

An ancient porphyritic lava containing numerous crystals of hornblende, from Vesuvius.—The phosphoric acid was here very distinct, but not so abundant as in the more recent lava.

A specimen of tufa, or *volcanic mud*, also from Vesuvius, was found to contain phosphoric acid in notable quantity.

These were all the substances tried; they were taken, as is at once seen, indiscriminately from igneous formations of many localities and many ages, and they all, with one doubtful exception, in which practical difficulties interfered with the inquiry, yielded phosphoric acid. It is highly probable, therefore, that this substance is a very usual, although small, component of volcanic rocks.

It is not unlikely that the remarkable fertility possessed by soils derived from the decomposition of some varieties of lava may be, *in part at least*, due to the presence of this phosphate in the original rock, although much must of course be ascribed to the alkali, especially potash, which these substances contain, and which is gradually brought by the continued process of disintegration into a soluble state. There can be little doubt that the matter erupted from time to time from the interior of the earth, in a state of fusion, is thus destined to renew the surface from which the more valuable and more soluble components have gradually been removed by the action of water and other causes constantly in operation. If it should hereafter be found on a more extended investigation that phosphoric acid, although present in all igneous rocks, is most abundant in those of modern date, the fact will thus receive an explanation, the more ancient lavas having been most changed by the slowly-acting and almost imperceptible causes in question. One might be tempted to consider lava as a kind of fundamental material, from the subsequent alteration of which all others are derived, and expect it to contain, here and there at least, traces of all the elementary bodies known, even those most rare. In the present case, it cannot be altogether devoid of interest to trace to its first source the enormous quantities of phosphoric acid, for the most part locked up in a temporarily insoluble condition in the vegetable and animal kingdoms, and in the various strata of calcareous and sedimentary deposits, in the formation of which organized beings have played so prominent and so important a part.

6 *Coventry Street*,
April 17, 1844.

This result seems in accordance with the inference, that all fishes are not cold-blooded. In the work already referred to, reasoning from the smaller size of the respiratory nerves of the *Pelamys Sarda,* compared with those of the Tunny, I offered the conjecture that its temperature would be found less than that of the Tunny, and somewhat higher than that of fishes of other orders with still smaller respiratory nerves, a conjecture which the observations described may be adduced as confirming.

In connexion with their temperature, my attention was directed to the blood of these fishes. I have been able to examine it only in three instances, and that partially, viz. the Sword-fish, the *Pelamys Sarda,* and the common Tunny. Considering the great difficulty there is in obtaining the subjects for experiment under favourable circumstances for examination, imperfect as were my results, I am induced to offer them now.

The Sword-fish appears to abound less in blood than the Pelamides, and the Pelamides less than the common Tunny; and accordingly the muscles of the former two are of a much lighter colour than those of the latter.

The blood of the Tunny is very rich in red particles: this is indicated not only by its appearance, but also by its specific gravity, which I have found as high as 1·070. The blood tried was taken from a fish, caught in the sea of Marmora, that weighed between two and three hundred pounds.

The blood of the Pelamides appears to be less rich in red particles than that of the Tunny, but more than that of the Sword-fish: I have not ascertained its specific gravity. The specific gravity of the blood of the Sword-fish I have found to be 1·051; the fish from which the blood was taken was caught in the Bosphorus, in the month of December, and was of large size.

Under the microscope the appearance of the red particles of the blood of these three fishes is very similar. They are commonly thin oval discs (very soft), containing oval nuclei: a few circular discs are intermixed with them. The medium dimensions of those of the Pelamides were about $\frac{1}{2000}$th of an inch by $\frac{1}{8000}$th; of the Sword-fish, about $\frac{1}{8000}$th by $\frac{1}{4000}$th; and of the Tunny, about $\frac{5}{8000}$th by $\frac{3}{8000}$.

That the red particles constitute that portion of the blood which is chiefly concerned in the production of animal heat, is now generally admitted. What a contrast appears, in comparing the blood of the fishes under consideration, with that of some of the colder, especially of the cartilaginous kind, in which it is very small in quantity, accompanied by a proportionally diminutive heart, and poor in red particles! the blood of the *Squalus Acanthias* I have found to exceed in density only a little its serum, one being of the specific gravity 1·030, the other of the specific gravity 1·027.

Whether the peculiar constitution of the red particles operates in any way in promoting their union with oxygen, seems to be deserving of consideration. It may be thrown out as a conjecture, that the circumstance of their possessing nuclei may have an effect of the kind, supposing, which is possible, the blood-corpuscle and nucleus, or containing and contained part, to be in the electrical relation to each other of positive and negative. If it be objected to this, that as regards nuclei as well as size, there is an analogy between the blood-corpuscle of fishes, birds and reptiles, the temperature of which commonly is so very different, it may be answered, that in all these classes such a constitution of blood-corpuscle may be designed for the same end, and that birds partly owe their high temperature to it; and that in reptiles and fishes, in most of which the proportion of red particles is small, were the constitution of blood-corpuscle different, it would be inadequate to perform the part required of it.

II. *On the Temperature of Man in advanced age.*

Not aware of any observations having been published on the temperature of man in advanced old age, I have been induced to institute some trials, the results of which I shall now briefly describe.

1. 91 years of age; feeble on his legs, but in pretty good health; a native of Grasmere in Westmoreland, where he has always resided, in easy circumstances, cultivating his own land. In June, when the temperature of the air was 60°, a thermometer placed under the tongue rose to 99°·5; his hands were warm; his pulse at the wrist 48, strong, intermitting. The observation was made at 2 P.M.; he had dined at noon. On the 28th of the October following, his temperature was again tried, about the same time of day, when the open air was 42°, the air of his room 52°; now, under the tongue, the thermometer was 98°·5; the pulse 56; his state of health much the same as before.

2. 88 years of age, also a native of Grasmere, where he has mostly resided, as a day labourer; is pretty firm on his feet, but troubled with chronic cough and difficulty of breathing. In June, when the temperature of the air was 60°, a thermometer placed under the tongue rose to 99°·5; his pulse was 56, and rather feeble; he had dined three hours previously. On the 28th of October, an hour after dinner, when his pulse was 70, the thermometer under the tongue was 98°; the air of the room 55°. In February, about three hours after dinner, when his pulse was 44 and feeble, the temperature under the tongue was 96°. This was on the 27th, the air then of his room was 44°; the open air about 32°, after a heavy fall of snow, and a sharp frost of several days' duration. The old man was feebler than in the summer and autumn; and though he did not complain of cold, his hand felt cold.

3. The wife of the preceding, the mother of several children, 76 years of age; hale for her years, but blind from cataract complicated with amaurosis. Her temperature, tried at the same time as her husband's, in June, was found under the tongue to be 98°·5, her pulse 78, and pretty strong. Tried again in October, it was found to be 98°, with a pulse of 70; and again in February, on the 27th, it was found to be 99°; her pulse being 80.

4. 87 years of age, a native of Ambleside, where she has commonly resided; feeble, but, excepting chronic cough, in tolerable health. On the 26th of October, at 3 P.M., the temperature under the tongue was found to be 98°·5; her pulse 84, and pretty strong; the air of the room then was 57°, the open air about 42°.

5. On the same day, and in the same village, tried the temperature of another old inhabitant, 92 years of age. The thermometer under her tongue stood about 98°; it could not be determined with perfect exactness, on account of the tremulous motion of her head, which also affected the limbs, preventing the counting of her pulse; her general health was pretty good.

6. An inhabitant of Ambleside, by trade a hatter, 89 years of age, hale, able to walk to church. On the 27th of October, when the air of his room was 56°, the outer air 42°, his pulse 64, strong and regular; the thermometer under his tongue stood at 98°. Observed again on the 27th of February, at 1 P.M., just after dinner, when the outer air was 32°, the air of his room 54°, the temperature under his tongue was found to be 99°·5; his pulse 70.

7. The temperature of his wife, two years younger, taken on the 27th of October, was 98°·5; her pulse was 88, irregular; she was very infirm and suffering from asthma.

8. A native of Scotland, 95 years of age, now residing in Ambleside, where he has been many years, always in good health, still tolerably strong and active. On the 28th of October found his temperature under the tongue 98°·5; his pulse 56, intermitting; the air of his room 57°. The old people in all the preceding instances, at the time the observations were made, were sitting by their fireside, as is their usage in the cool climate of Westmoreland, the greater part of the year, and all of them, with one exception, seemed to be comfortably warm; the poorest of them were not in want.

Old age is commonly represented as cold, and the temperature of the body is commonly supposed to diminish with advancing age. The results of the preceding observations generally are not in accordance with this opinion; they seem on the contrary to show, that the temperature of old people, at least as regards the deep-seated parts, of which the tongue at its base may be considered as some indication, is rather above than below the average temperature of middle age, taking that to be about 98° of FAHR. Nor, perhaps, is this surprising, when we reflect, that most of the food consumed by old persons—and their appetite generally is good—is probably chiefly employed in administering to the function of respiration, being very partially expended in meeting the waste of the body.

Probably in very advanced old age, as in very early infancy, the power of resistance to cold is feeble, and the temperature of the body is easily reduced on exposure. An observation which I made many years ago in Ceylon would seem to be confirmatory of this. At 7 o'clock in the morning, when the air was 72°, I tried the temperature of an old man, almost a century old, and of a boy about twelve years old, both cool, being thinly clad and out of doors; the temperature of the old man under the tongue was 95°; in the axilla 93°; that of the boy under the former 98°, and in the latter 96°·5. The observation too on the old man in Grasmere, made in February in cold weather, is also favourable to this conclusion: whilst those made at the same time, on the other two old persons in stronger health, seem to show, that, provided there is a vigorous action of the heart and free circulation of the blood, the temperature of the body is easily maintained.

III. *On the Effect of Air of different Temperatures on Animal Heat.*

As from observations made on man on entering the tropics, and within the tropics on descending from a cool mountainous district to a hot low country, it would appear that his temperature as measured by a thermometer placed under the tongue is liable to fluctuate,—rising one or two degrees in a warm atmosphere, and falling as much on entering a cool one *,—it seemed probable that like differences of effect might be produced by air kept at different degrees of temperature in buildings in this country.

In the autumn of last year, when going through the cotton manufactory of Deanstone, in the neighbourhood of Doune in Stirlingshire,—an establishment admirably conducted and in the highest order,—I availed myself of the opportunity to try the temperature of a few individuals in relation to this question. In the room called the "piecing-room," where a high temperature is always required on account of the kind of work,—a temperature kept up by means of warm air and steam,—when at 92°, I found the thermometer placed under the tongue of one man who had been at work there about six hours, rise to 100°·5; and of another, who had been there the same time, to 100°: the former was 52 years of age, healthy, his pulse 64; the other 33 years of age, in pretty good health, but liable to acidity of stomach; his pulse 78.

In an adjoining room, where the temperature of the air was 73°, the thermometer placed under the tongue of a young woman rose to 99°; and in a large room, where 300 persons were employed in weaving, and where the temperature of the air was 60°, the thermometer placed under the tongue of another healthy young woman rose only to 97°·5.

Few as are these observations, they seem to warrant the conclusion that a high temperature of even a few hours in the heated air of a room is capable of raising the temperature of the body above its usual standard, in accordance with what had been anticipated from the effect of different degrees of atmospheric temperature.

In further confirmation of the same, I may briefly state the results of multiplied observations made on the temperature of the same individual. The subject of them was of middle age, in good health, under whose tongue the thermometer commonly was stationary at 98°, when neither suffering from heat nor cold. The place where they were made was Constantinople,—the climate of which capital, it may be observed, is exceedingly variable,—often cold in winter and the early spring, and commonly very hot in summer,—liable to great vicissitudes from its situation on the confines of two seas, in regard to warmth very different in character during a great part of the year. The observations were begun early in March, and were continued at intervals till the latter end of July. During this time the thermometer in the open air ranged from 31° to 94°, and the temperature observed under the tongue from 97° to 99°·5. It may not be amiss to mention some particular instances.

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* *Op. cit.* i. 169.

On the 5th of March, after having been exposed several hours in an open boat on the Bosphorus, with a strong wind at 43°, the thermometer placed under the tongue stood at 97°.

On the 11th of the same month, when the ground was covered deeply with snow, and the thermometer in the open air at 7 A.M. was 31°, and in a bed-room 45°, the temperature under the tongue was found to be 97°·5.

On the 3rd of April, when the thermometer in the room, with the window open, was 66°, under the tongue it was 98°·5.

On the 17th of July, when the thermometer was 87°, under the tongue it rose to 99°·5. On the 21st of the same month, when the air was 87°, the temperature under the tongue was 99°·5; and on the 28th, when the former was 94°, the latter was 99°.

During the hot weather of July, it may be deserving of remark, that the pulse was less affected than the respiration, which habitually about sixteen in the minute, was now commonly fourteen, and one day did not exceed twelve.

It may also be mentioned that attention was paid to the temperature of the extremities, and also to that of the urine, and that commonly it was found of highest temperature when the tongue and extremities were of lowest temperature: thus, on the 5th of March, when the thermometer under the tongue was 97°, the feet and hands cold, in the urine it rose to 101°; and on the 28th of July, when under the former it was 99°·5, in the latter it was the same.

Do not these observations, besides tending to confirm the preceding conclusion for which they were brought forward, viz. that the temperature of the body rises and falls in a perceptible manner with the temperature of the air, lead also to the further conclusion, that the tendency of a high temperature of atmosphere is to raise the temperature of the surface and of the parts adjoining the surface in a somewhat higher ratio than the deep-seated organs; and of a low temperature of atmosphere to raise the temperature of the deep-seated parts, whilst that of the surface is subjected to undue reduction from the cooling agencies to which it is exposed, directed, as it were, in both instances, for a beneficial result, on the principle of compensation?

IV. *On the Effect of Exercise on the Temperature of the Body.*

This subject of inquiry, notwithstanding its manifest importance, has been much neglected; indeed, I do not know of any work in which any precise information is to be obtained respecting it.

The observations which I have to offer are fewer than I could wish and more limited; they were made at Constantinople in 1841, at intervals between February and August, and had for their object mainly to endeavour to determine the effect of moderate exercise in walking on the temperature of the body. The individual on whom they were made was the same as was mentioned in the last section. The particular observations are the following:

February 19th, at 1½ P.M., air of room 60°; before walking, feet cold, temperature between the toes 66°; under the tongue 98°; urine 100°. At 5½ P.M., open air 40°; just returned from a walk, gently warmed by the exercise; feet and hands warm; the former 96°·5, the latter 97°; under the tongue 98°; urine 101°.

March 2nd, at 4½ P.M., open air 50°; air of room 66°; feet and hands moderately warm; the former 75°, the latter 81°; under the tongue 98°; urine 100°. At 5½ P.M., after having walked pretty quickly an hour, a gentle perspiration produced, the hands and feet hot, found the latter 99°, the former 98°; under the tongue 98°; the urine 101°·5.

March 20th, at 5½ P.M., open air 42°; returned warm after a walk of three hours: the hands, which had worn warm gloves, were 99°; feet 97°; under the tongue 98°; the urine 101°·5.

April 7th, after a walk of three hours in the open air, between 60° and 70°, returned at 5 P.M., gently perspiring: the hands were 94°; the feet 96°·5; under the tongue 98°·5; the urine 100°·5.

May 27th, at 6½ P.M., after a walk of an hour and half, the air 68°, returned slightly perspiring; the hands were 95°; the feet hot; under the tongue 99°·5; the urine 101°·5.

May 28th, air 65°; under the tongue before taking exercise 98·°5: after a walk of four hours and half, gently perspiring, under the tongue 98°; hands 93°; feet 97°·5; urine 100°·5.

September 13, at 4 P.M., the open air on the shore of the Bosphorus 76°: ascended in about twenty minutes, without stopping, the steep side of the hill, called the Giant's Mountain; on reaching its summit, when profusely perspiring, the pulse was 102°, usually about 52°; the hand 98°; under the tongue 98°. The pulse of another individual in company, of about the same age, also profusely perspiring, was 138°; thermometer under his tongue 98°; and in the hand the same. After descent, the pulse of the former was 94°; thermometer under his tongue and in the hand 98°·5; the pulse of the latter was 112°; the thermometer under his tongue 98°·5; both only gently perspiring.

What is the inference from these observations? Do they not seem to indicate that whilst moderate exercise promotes the diffusion of temperature and its exaltation in the extremities, it augments very little, if at all, the heat of the deep-seated parts? And considering the blood as the heating medium, warmed itself chiefly by respiration, is not this what might be expected, reasoning on the subject? By active exercise, the pulse and the respiration are both accelerated; more oxygen, it may be presumed, is consumed, more heat is generated; the blood is made to circulate more rapidly, and is sent in larger quantity into the extremities, and where, in consequence, the excess of heat is conveyed and expended, and its accumulation in the central and deep-seated organs prevented, affording another striking example of harmonious adaptation.

The same thermometer was employed in making all the observations described in this paper; and in every instance, in stating the results, allowance has been made for error in its graduation, carefully determined by comparison with a standard instrument, one belonging to Professor **Forbes** of Edinburgh, and for the use of which I have been indebted to his kindness.

The Oaks, Ambleside,
Nov. 1st, 1843.

VI. *A Description of certain Belemnites, preserved, with a great proportion of their soft parts, in the Oxford Clay, at Christian-Malford, Wilts.* *By* RICHARD OWEN, *Esq., F.R.S., &c.*

Received March 14,—Read March 21, 1844.

THE extinct Cephalopod, called *Belemnite*, has long been known by its peculiarly complex shell, which includes a part possessing the chambered and siphonated structure characteristic of the entire shell of the *Spirula* and *Nautilus*, and the fossil *Orthoceratites*, *Baculites*, *Ammonites*, &c. Like the latter unequivocal congeners of the still existing Nautilus, the Belemnites are distributed through a vast series of the secondary rocks from the epoch of the muschelkalk, when they seem first to have been introduced into the old ocean of this planet, up to the Maestricht chalk, when they finally perished.

No fossil shell has more exercised the ingenuity and research of the interpreters of ancient Nature, or has given rise to so many conflicting opinions as to the affinities of its animal constructor, than the Belemnite: but the specimens from the Oxford clay near Christian-Malford, in Wiltshire, liberally presented by the Marquis of NORTHAMPTON, P.R.S., SAMUEL PEACE PRATT, Esq., F.R.S., and WILLIAM JOHN BRODERIP, Esq., F.R.S., to the Royal College of Surgeons, leave no reasonable ground for further hesitation or scepticism on the subject, since they display in a truly marvellous manner, those soft and seemingly most perishable parts of the animal which are essential to convey a true idea of its living form.

It must, however, be premised in vindication of the fruitful principle of physiological correlations, established by CUVIER as the key to the interpretation of fossil remains, that, for some years prior to this discovery, there had been obtained sufficient evidence of the organization of the Belemnite, to determine both its ordinal and family affinities; but, as the value of this evidence failed to be appreciated by some experienced palæontologists, from want of sufficient knowledge of, or faith in, the laws of the interdependencies of the characteristic parts of the Cephalopodal organization, the additional facts afforded by the well-preserved specimens from the Oxford clay are most acceptable and valuable.

In the compound shell of these specimens the following parts are recognizable:—

1st. The terminal spathose body called the '*guard*,' sheath or rostrum*, resembling the head of a dart or javelin, whence the name Belemnite originally given to this part of the shell, which is usually the only part preserved, and now extended in its application to the entire animal.

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* Plate II. fig. 1, *a*.

2nd. The chambered or siphonated part of the shell which I have called the '*phragmocone*[*],' and which is lodged in the conical alveolus or cavity at the base of the 'guard.'

3rd. The conical, thin, but dense, corneo-nacreous case[†], which immediately invests the phragmocone, and lines the alveolus of the guard; commencing at the bottom or apex of that cavity, and continued beyond the thin margins of the basal aperture of the alveolus, and beyond the last septum of the phragmocone, to form, as Dr. Buckland rightly describes[‡], the large anterior chamber of the Belemnite containing the ink-bag and some other viscera.

The numerous species of Belemnite have been classified according to the modifications of the spathose guard; the one under consideration belongs to the group characterized by a rounded, elongated, conical guard, with a short, terminal, ventral, longitudinal impression; it was first recognised as a new species by Mr. Pratt, who has honoured me by naming it *Belemnites Owenii*. This species approximates in its general form to the *Belemnites elongatus* and *Bel. longissimus* of Miller, from the lias; but it presents intermediate proportions of length to breadth, and maintains the same diameter throughout a much greater part of its extent; the anterior expansion, which is very gradual, commencing, nevertheless, nearer the alveolar extremity, and ending less widely. The excavated part of the guard becomes very thin as it expands, and, there having been no infiltration of mineral matter into its cavity, or into the chambers of the phragmocone, it has yielded to the pressure of the superincumbent strata, and thus in its flattened and fractured state shows a greater degree of expansion than is natural to it. The thin and brittle margin of the spathose alveolus may be traced nearly half way towards the base of the phragmocone, which is there invested only by the thinner and more yielding corneo-nacreous sheath[§].

The gradual expansion of the guard from its posterior end or apex is shown in the figure 1. The ventral groove (fig. 2 a') extends to about one-fourth the length of the guard, commencing a little in advance of the apex: it is very shallow, with the

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[*] Pl. II. figs. 1 *c*, 6, 7 and 8. *Φραγμὸς* partition, *κῶνος* cone. Lectures on Comparative Anatomy, 8vo, 1843, p. 333. The term 'alveolus' has usually been applied to the chambered cone; but it appears better to restrict it to the socket in which the chambered cone is lodged.

[†] Pl. II. fig. 6, and fig. 7, *η*.

[‡] Bridgewater Treatise, 1836, p. 372.

[§] In the specimen of *Belemnites elongatus* figured by Miller (Geol. Trans. 1826, Pl. VII. fig. 6.), this thin sheath, which extends beyond the wider part of the alveolus, had perished, as is usually the case, and the casts of the chambers of the phragmocone, which is preserved *in situ*, are exposed. To this is due the appearance which M. De Blainville was unable to understand in the figure above cited. "Ce que je ne conçois pas dans cette figure, c'est la manière dont les calottes empilées, qui constituent l'alvéole, dépassent de beaucoup la cavité de la coquille ou du tube, dont les bords sont cependant assez amincis pour croire que le péristome est parfait."—*Sur les Belemnites*, p. 95, 4to, 1827.

Fig. 5.

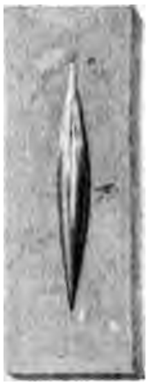


Fig. 1.

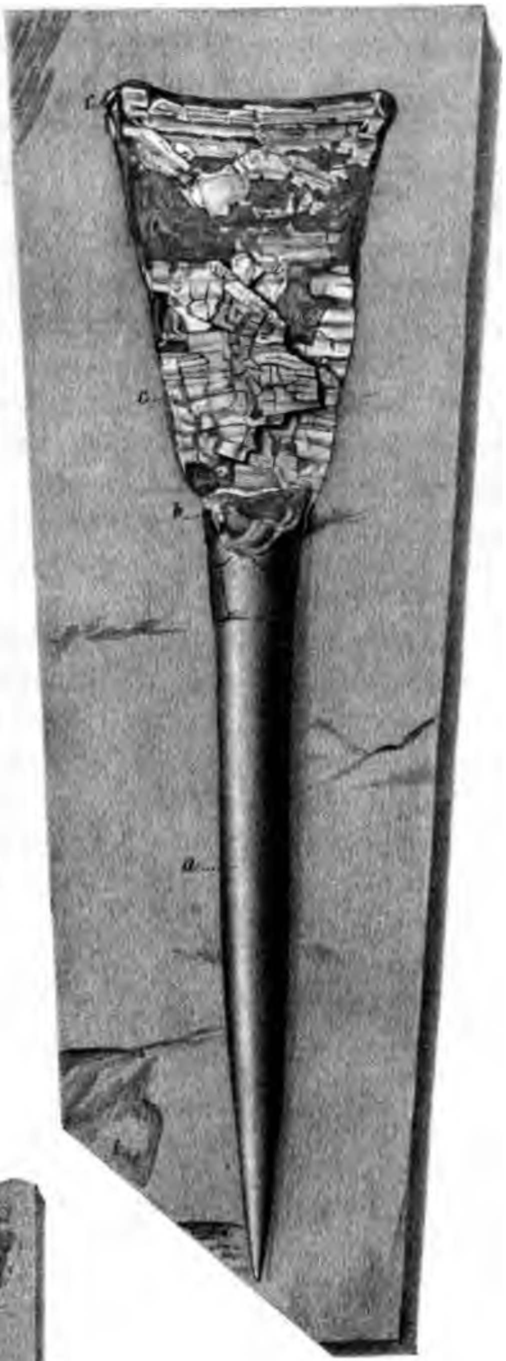


Fig. 4.

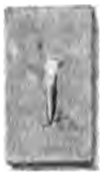


Fig. 3.

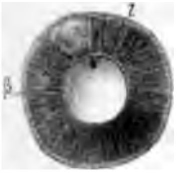


Fig. 8.

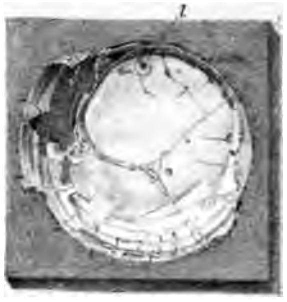


Fig. 2.

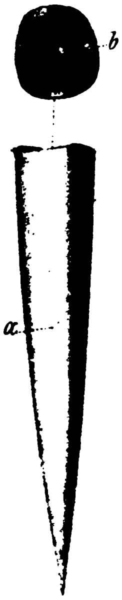


Fig. 7.

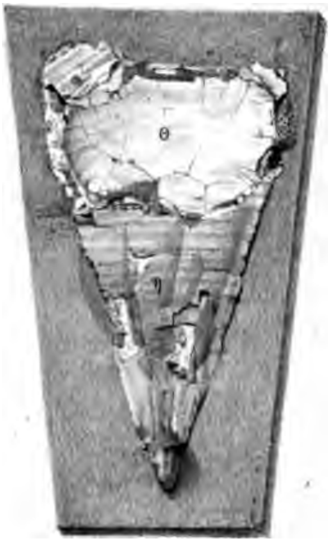
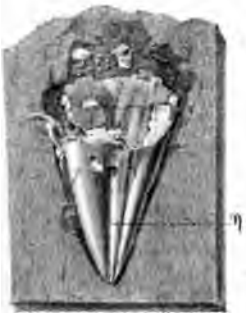


Fig. 6.



J. Basire, Zincog.

bottom not rounded, but defined by two parallel lines. The posterior half of the guard is slightly compressed laterally, and a very faint trace of a longitudinal impression may be discovered on each side, rather nearer the ventral than the dorsal surface. One of the specimens of the *Belemnites Owenii,* presented to the College of Surgeons by Mr. Broderip, measures eleven inches from the apex of the guard to the basal partition of the phragmocone: the diameter or breadth of that partition is one inch and a half: the length of the guard from its apex to the beginning of the crushed alveolus is six inches: the length of the ventral groove is one inch and a half.

With respect to the guard, I have little to add to the excellent descriptions of former authors, besides an account of its microscopic structure[*]: but this is the more requisite, as in some recent and estimable works the spathose structure is still regarded as the result of accidental posthumous infiltration. The guard consists of numerous, thin, for the most part concentric, layers[†] of minute prismatic trihedral fibres[‡], placed at right angles, or nearly so, to the planes of the layers: the crystalline fibres are indicated by lines which radiate from the central axis and cross the lines of growth: the lines which define the fibres, when magnified 150 diameters, are seen in many parts of the section to run in pairs with a minutely and gently undulating course, resembling the tubes of dentine, but differing in the transparency of the intercepted calcareous matter, which is like that in the wider spaces separating the pairs of lines.

These differences in the intervals of the radiating fibres may depend on the different parts of the prismatic fibres divided in preparing the sections made parallel to their course.

There is an appearance not uncommon in microscopic sections of the spathose guard, which, though due to minute splintering or abrasion of the surface, is too characteristic of the texture of the guard to be passed over; it is produced by a number of elongated triangular specks[§], defined by their opacity when the section is viewed by transmitted light, and by their white or silvery surface when viewed by reflected light: the long axis of these triangles is always parallel to the fibres, and transverse to the layers; but on one side of the section the apices are turned towards the centre, on the other side towards the circumference of the guard; so that a slight change of focus reverses the position of the triangular specks.

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[*] This was first noticed by Dr. Carpenter in his valuable paper 'On the Microscopical Structure of Shells,' in the following words:—"The solid conical sheath of the Belemnite is a very favourable subject for microscopic examination; and of this I have made numerous sections. The greater part of these appear to have almost completely lost any indications of organic structure they may have once presented, being almost or completely homogeneous in their aspect. In some, however, I have met with a structure, which so closely resembles that of the massive *Septaria gigantea,* that I have no hesitation in the belief, that the shell of the latter is the nearest living analogue of the sheath of the Belemnite. I consider the term 'fibro-calcareous,' applied to the latter by Dr. Buckland, to be therefore erroneous; the structure being referable to the general type of membranous shells. The membrane seems to have been corrugated in a radiating direction, and as the deposition of calcareous matter followed the same, an appearance of radiating fibrous structure is given on fracture, which exactly corresponds with that of *Septaria.* The only difference between the two cases seems to have been, that, in the Belemnite the deposit took place from within outwards, whilst in the Septaria it was from without inwards."—*Extract from a Paper on the Microscopical Structure of Shells, by* William B. Carpenter, *M.D. Read to the Royal Society, December* 22, 1842.

[†] Pl. VII. fig. 1, β.

[‡] Ib. fig. 1, γ; fig. 2, δ.

[§] Ib. fig. 1, ε.

The lines produced by the concentric layers of growth are seldom marked with equal distinctness; the strongest ones are usually in groups of three, five, or eight, with fainter lines in the clearer interspaces: this appears due to the varying thickness of the animal membrane at the contiguous surfaces of the layers of the prismatic fibres, which membrane was either formed by, or afforded attachment to the extremities of the delicate membranous cells which served as moulds for the calcareous matter of the fibres. The impress of these extremities has produced on many of the lines of growth a minutely undulating or crenate course. The layers of growth vary slightly in thickness; many are brought into view by applying a magnifying power of 150 diameters to a transparent section of the guard which otherwise would escape notice; those only being visible to the naked eye that are separated by the thicker lines; they are thus seen to be much more numerous than the septa of the phragmocone. In a transverse section through the middle of the alveolus, eighty layers could be counted in a thickness of a line, and more than three hundred in the solid part of a guard whose semidiameter was four lines.

A longitudinal section of the guard through its centre, and a transverse one, both demonstrate the longitudinal course of the radiating fibres, the linear indications of which might be interpreted as the folds of a plicated membrane: a longitudinal section taken near the circumference of the guard cuts across the radiating fibres, the extremities of which are thus seen in transverse section; their distinct and independent character and trihedral form are then clearly demonstrated, as in Pl. VII. fig. 2: they vary a little in size, the average diameter being $\frac{1}{2000}$th of an inch.

Through a great part of the thickness of the guard next the outer surface, the thin fibrous conical layers are concentric, progressively increasing in length as they approach that surface, and thus forming the alveolus or cavity for the phragmocone. The innermost or first-formed layers are not parallel with the outer ones, but recede from them at their anterior end, contracting as at the opposite end, but in a less degree, so as to form a slender cylindrical stem, sometimes slightly dilated at the end which is in contact with the apex of the capsule of the phragmocone. The interspaces thus left between the earlier and the later layers of the guard are occupied by more abundant animal membrane, mixed with coarser opake calcareous particles, like those which harden and render brittle the corneo-nacreous capsule of the chambers; a filamentary tract of the same kind of matter is continued from the apex of the above capsule down the centre of the guard to its posterior apex.

Mr. Pratt has obtained from the Oxford clay at Christian-Malford the guard of a young Belemnite, three lines long*, fusiform, slightly contracted posteriorly;

* Pl. II. fig. 4.

this must have belonged to an animal just excluded from the egg, if excluded at all. The layers of growth immediately added to this axis extend beyond it, both anteriorly and posteriorly; and, being thicker in the middle than at the two extremities, render the guard fusiform, as in the young specimen rather more than an inch in length* from the same stratum and locality as the preceding. At this stage of growth, which lasts longer in some species, as the *Belemnites subfusiformis*, than in others, the spathose guard has been mistaken for the spine of an Echinus, and this idea, first entertained of Belemnites in general by **Klein**, has been reproduced in later times by M. **Raspail**: even the sagacious Mr. **Miller**†, who has done so much towards the elucidation of the Belemnites, was led to conceive the fusiform guard of immature individuals to be remains of a distinct genus, for which he proposed the name of *Actinocamax*‡.

The exterior surface of the spathose guard of the Belemnites of the Oxford clay, though smoother than in some other species, is minutely granular, and occasionally presents faint traces of vascular impressions, proving it to have been invested by an organized membrane of the living Cephalopod. On two specimens from this conservative stratum, I have detected remains of a more immediate investment of a thin friable layer of white calcareous matter, analogous to that of the outer layer of the sheath of the phragmocone. The animal membrane or constituent of the spathose guard has been alluded to by Dr. **Buckland** as being evidenced by the odour resembling burnt horn, produced on burning this part of the Belemnite. I will only add in reference to the spathose calcareous constituent, that its microscopic structure proves it to be an original formation, deposited in membranous cellular moulds, under the influence of the vital organizing forces, and not to be the result of post-mortem infiltration of mineral substance, into an originally light and porous, or cellular texture, as **Walch**, **Parkinson**, **Lamarck** and **De Blainville**§ have conjectured.

As respects the phragmocone and its investing sheath, the well-preserved Belemnites of the Oxford clay demonstrate that the sheath is continued backwards to line the alveolar cavity of the spathose guard, as well as forwards from its basal outlet to form the visceral chamber anterior to the phragmocone. The phragmocone in these specimens appears broader than it actually was on account of the compression which its frail walls have been unable to resist; its basal part is usually squeezed flat, but sometimes one of the septa has slipped forwards so as to present its surfaces to the planes of pressure, and so retain its original form: one of these, which shows likewise its natural slight concavity, demonstrates the marginal position of the siphon as in other Belemnites, Pl. II. figs. 3 and 7, ι.

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* Pl. II. fig. 5.

† His conjectural figure of the recent Belemnite (Geological Transactions, new Series, vol. ii. (1826) Pl. IX. fig. 15) is essentially the same with those which have been since published by Dr. **Buckland**, M. **D'Orbigny** and M. **Duval-Jouve**.

‡ M. **Duval** (Mém. sur les Belemnites, 4to, 1841, p. 68) has demonstrated, what MM. **De Blainville** and **D'Orbigny** suspected to be, the true nature of the *Actinocamax* of **Miller**.

§ Sur les Belemnites, 4to, 1827, pp. 32, 33. Specimens of the spathose guard have been discovered which have been fractured during the life-time of the Belemnite, and healed; the broken portions having been held together by the surrounding organized integuments, and reunited by the deposition of new layers of the fibrous structure peculiar to the guard. **Duval-Jouve**, Sur les Belemnites, p. 37, Pl. X.

The septa are composed chiefly of nacre with a thinner layer of white friable calcareous matter on both surfaces, which is seldom preserved. I have found twenty septa in an extent of two inches from the base of the phragmocone; about an equal number of septa dividing chambers progressively diminishing in depth, and more rapidly in width, are indicated, by detached phragmocones, to have extended to the apex of the socket of the guard. The capsule of the phragmocone consists of a thin layer of mixed albuminous and opake calcareous matter, lined with nacre, but with a yellowish smooth outer surface. In Lord Northampton's well-preserved specimen, it terminates by a well-defined margin a little in advance of the ink-bag, forming there the true peristome of the shell, as shown in fig. 9.

The entire phragmocone, with its capsule, of these Belemnites from the Oxford clay, has been found not unfrequently isolated and detached, having slipt out of the alveolar cavity of the guard; such specimens are squeezed flatter than those which have remained in and been protected by the guard. The yielding texture of the phragmoconic capsule has commonly caused it to fall into longitudinal folds when compressed, after having become detached from the alveolus. In two specimens in the collection of Mr. Cunnington of Devizes these folds are well-marked, regular, and on the same side of the capsule, forming two longitudinal grooves* in one and three in the other, the intermediate risings being so well defined as to appear like a structure original and natural to the capsule; but their position is different, and the degree of the indentation varies, and in other specimens the partial longitudinal impressions are barely discernible. If the change of form caused by the compression were not borne in mind, these piles of concave plates would seem not to have been adapted to the alveolus, and might thus be made occasions for the revival of the exploded idea of De Montfort, that the phragmocone of the Belemnite belonged to an animal generically distinct from that which had constructed the spathose guard.

Belemnites whose remains have been left in strata percolated by streams containing mineral matter in solution, have the chambers of the phragmocone filled with crystals consequent upon such calcareous or siliceous infiltration: in the present Belemnites from the Oxford clay, no such infiltration has taken place subsequent to interment; we find only the delicate original calcareous framework of the phragmocone, crushed and squeezed out of its original shape, whilst the solid part of the spathose guard, by virtue of its proper primitive fibrous structure, has retained its cylindrical figure. This fact, independently of the microscopic evidence of organization, suffices to prove that the weight and solidity of the guard had received no augmentation by inorganic influences after death[*].

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* Pl. II. fig. 6, η.

That the shell of the Belemnite was due to the formative forces of the mantle of a molluscous animal, was the sound speculation as to its nature, which our countryman Joshua Platt first recorded in the Transactions of the Royal Society for 1764. The presence of a camerated and siphonated structure in this complicated shell, led Walch[†] and Guettard[‡], and after them most subsequent conchologists, to class the Belemnites with the Baculites, Orthoceratites, and other more simple chambered shells. Mr. Miller, having detected evidence of the internal position of the belemnitic shell, compared it, as Deluc[§] on other grounds had done, with the internal shell of the Cuttle-fish, and first ventured on a conjectural restoration of the entire animal. He thought the Belemnite to have been an intermediate form in the Cephalopodal class, uniting the internal multilocular shell of the *Spirula* with the laminated calcareous plate of the *Sepia*, to which the belemnitic guard appears to correspond; and, believing that the *Nautilus*, *Ammonite*, *Sepia* and *Loligo*, had the same organization (only the *Dibranchiate* type of Cephalopodal structure being then known), Mr. Miller placed the belemnitic shell in the body of a Calamary (*Loligo*), assigning to the terminal fins the office of clasping the guard and retaining it in its proper position; which last idea M. De Blainville very justly rejected.

The subsequent discovery of two grades of organization in the class of Cephalopods, consequent on the dissection of the *Nautilus Pompilius*[‖], called for a closer investigation of the affinities of the Belemnites, and led to an attempt to establish a more definite approximation of these with the other families of siphoniferous Cephalopods, now ranked under two distinct orders of the class.

The first evidence that bore directly upon the question of the position of the Belemnite in this class, was detected by Dr. Buckland[¶] and M. Agassiz[**] in specimens of Belemnite from the lias at Lyme Regis, in which the fossil ink-bag was preserved in the basal chamber of the phragmocone, or that formed by the anterior prolongation and expansion of its capsule.

The importance of this discovery depends chiefly on the facts, that the secreting gland and reservoir of the inky secretion common to all the naked Cephalopods do not exist in the recent *Nautilus Pompilius*, and that no trace of them has ever been met with in connection with any of the simple or typical forms of fossil chambered shells, as the *Orthoceratites*, *Baculites*, *Ammonites*, &c.

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[*] Such was Mr. Miller's opinion; but, as it was unsupported by microscopic investigation, or by any facts like that above cited, it was not accepted by Prof. De Blainville and Dr. Buckland.

[†] In Knorr's 'Recueil de Monumens des Catastrophes que le Globe de la Terre a essuyeés,' &c. fol. 1768.

[‡] Mémoires sur différentes parties des Sciences et des Arts, t. v. 9e Mémoire, 1783.

[§] Mémoires sur les Bélemnites, in Journal de Physique, 1799, 1801, 1802.

[‖] Owen, Memoir on the Pearly Nautilus, 4to, 1832.

[¶] Philosophical Magazine, N.S. 1829, p. 388. [One of the specimens discovered by Miss Mary Anning of Lyme, on which Dr. Buckland's observations were made, has been presented, since the reading of the present memoir, by the Earl of Enniskillen to the College of Surgeons.]

[**] Ibid. 1834.

Reflecting on this marked difference in the anatomy of the Nautilus, I was led to perceive that, as this rare Cephalopod derived sufficient protection from its large and strong external shell, it might well dispense with that peculiar glandular apparatus which had before been deemed a common character of the Cephalopodal class; whilst on the other hand, as the highly organized naked Cephalopods enjoy active powers of locomotion which would be incompatible with the incumbrance of a heavy external testaceous defensive covering, they required a compensatory endowment of the power of secreting an inky fluid, which, when alarmed, they might inject into the surrounding water and conceal themselves by the dusky cloud thus occasioned. But the branchial character of the naked order of Cephalopods is an essential condition of their muscular powers; the presence of an ink-bladder, therefore, in the extinct Belemnites, would have implied the internal position of the shell, even if other proof had been wanting; and, by the laws of correlation, it implies likewise the presence of the muscular forces for rapid swimming, and the concomitant conditions of the respiratory, the vascular and the nervous systems. Connecting, therefore, all these considerations with the detection of the ink-bag in the shell of the Belemnite, I felt justified in referring the Belemnites, and likewise the Spirula, on account of the ascertained internal position of its shell, to the Dibranchiate order; and I therefore separated these chambered and siphoniferous shells from the Nautilus and the Ammonites, in the classification of the *Cephalopoda* submitted to the Zoological Society in February 1836*.

But the true grounds of this separation seem not to have been appreciated or understood by some Palæontologists. Professor Phillips, for example, in his excellent article on *Turrilites*, in the part of the Penny Cyclopædia published in January 1843, has observed, "The relations of Turrilites, Scaphites, Baculites and Hamites to Ammonites is very obvious; and, as through Goniatites, this great extinct group is certainly connected to the living and extinct *Nautili*, Mr. OWEN has ventured to include them all in the Tetrabranchiate Cephalopoda, leaving Spirula and the Belemnites with Sepia and the Dibranchiate types. However this may be, the determination of the relative affinities among the numerous fossil Cephalopods, a point of great importance, must be worked out with the help of other considerations than the respiratory system." In the memoir on the 'Classification of *Cephalopoda*,' above cited, it will be found that many other considerations than those of the respiratory system, and of equal importance with them, influenced me in forming an opinion of the natural position of the Belemnites in the class *Cephalopoda*.

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* Zoological Transactions, ii. pp. 127, 129. "The *Cephalopods* with internal chambered shells, heretofore classed with the *siphoniferous Cephalopods*, which constitute the preceding order, I would join with all the other *naked Cephalopods*, to form a second order, under the term *Dibranchiata*, having reference to the number of gills, viz. two. This number is constant in all the '*Seiches*' of Cuvier, and is associated with the presence of two branchial hearts, besides the single systemic heart, and with an ink-bag: there can be little doubt that the same type of structure is exemplified in the *Spirula*, from what has been determined respecting its external characters[3]." [3] "The discovery by Dr. Buckland of the remains of the ink-bag in the extinct *Belemnites*, justifies the conclusion from the laws of coexistence, that these *Cephalopods* also possessed two gills and two branchial hearts." In the same year, 1836, the Number of the Cyclopædia of Anatomy and Physiology was published, containing my Article '*Cephalopoda*,' in which it is argued of the *Belemnites*:—"As it is certain that the animals of this family of extinct *Cephalopods* possessed the ink-bag, they must consequently have been enveloped by a muscular mantle; and we may, therefore, infer that they resembled the *Dibranchiates* in their locomotive and respiratory organs, and consequently in the general plan of their organization. In the structure and position of their siphoniferous camerated shell, they are intermediate to *Spirula* and *Sepia*, and as the animal of *Spirula* is proved to be a *Decapod*, the probability is very strong that the animal of the *Belemnite* was of the same type."—p. 520,

LEOPOLD VON BUCH, who believed that he could trace in certain slabs containing Belemnites the impressions of the Cephalopods to which they belonged, concluded "that the body of the animal enveloped the greater part of the shell, and exceeded its length by eight or ten times*." Other considerations taken from the shell itself prove, as has already been shown, that it was wholly internal.

The specimen† presented to the Hunterian Museum by the Marquess of NORTHAMPTON, exhibits the phragmocone, the muscular mantle, a small part of the head, and a greater or less proportion of six of the cephalic tentacula which are armed with horny hooks in a double alternate series, as in the *Onychoteuthis gigas*.

The phragmocone with the soft parts of the Belemnite has been detached from the guard probably soon after death; and the whole squeezed nearly flat after becoming interred in the laminated clayey matrix. The resistance of the ink-bag (*n*) with its inspissated and indurated contents, has led to abrasion and loss of the walls of the part of the phragmocone covering it, and it seems to have been pressed downwards through one or two of the basal partitions deeper into the sheath than was natural, or than it is situated in other specimens. The capsule of the phragmocone extends about one-third of an inch beyond the ink-bag, and terminates by a well-defined border. The smooth surface of its opake white external calcareous layer is well preserved over nearly the whole of this part. The muscular tunic of the mantle (*d*) appears to commence at the peristome; it seems to have first undergone the change into adipocire and then to have become so brittle as to crack and break instead of bending to the pressure; the course of the muscular fibres is plainly visible; all those on the outer surface of the mantle which is presented to the observer, are transverse or circular; this surface is smooth, and the course of the fibres more feebly indicated; in the few places where the upper side of the mantle is broken away, and the inner surface of the opposite side shown, the arrangement of the transverse fasciculi is more strongly displayed.

In the length as compared with the breadth of the mantle, the Belemnite is shown by this beautiful specimen to have had the same elongated form of body as the *Onychoteuthis* and most modern *Decapoda*.

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* Oken's Isis, Bd. xxi. p. 438.

† Pl. III.

A little above the capsule of the phragmocone, on the left side, there is a flattened transversely fibrous body (*e*) with a rounded external border, so well defined as to excite the suspicion that it must have belonged to some part superadded to the muscular mantle; its nature is demonstrated in the specimen next to be described.

An oblong portion of the same fibrous and muscular tissue as the mantle, lying obliquely in front of the anterior margin of the mantle, and in which both a longitudinal and transverse layer of fibres are discernible, seems to be the remains of the infundibulum or expiratory tube (*f*).

The direction of the fibres in the cephalic arms is chiefly longitudinal; the magnified figure* precludes the necessity of describing the shape of the horny hooks; their arrangement in a double alternate series is manifested in some parts of the arms, but is still more obvious in the third specimen† to be described.

The second less complete but highly instructive specimen of the Belemnite‡ is from the collection of Mr. Pratt; it exhibits part of the muscular mantle (*d*), the two fins (*e, e*), apparently the infundibulum (*f*), the ink-bag and duct (*n*), and a considerable proportion of the phragmocone (*c*). This part is more distorted and less entire than in the preceding specimen, but, so far as a comparison can be made, presents the same form and structure§.

The reservoir of ink is situated two lines within the aperture of the phragmoconic capsule, which terminates with the same well-defined border; it is of an oval form and jet black colour, with a feeble indication of its original nacreous outer coating: the inspissated ink is very hard, brittle and splintering; when reduced to a fine powder it presents a dark brown hue, and, used as a pigment, works as smoothly as Roman Sepia, but with a deeper tint.

The Belemnitic ink-secretion offers the closest resemblance with that described by Dr. Buckland from the lias of Lyme Regis, and which he found associated with a series of circular transverse plates and narrow chambers, resembling the chambered cone within the alveolus of a Belemnite, and from which Dr. Buckland inferred that the animal, from which these fossil ink-bags were derived, was some unknown Cephalopod, nearly allied in its internal structure to the Belemnite, the circular form of the septa showing that they could not be referred to the molluscous inhabitant of any Nautilus or Ammonite‖.

The absence of the ink-apparatus in the Nautilus and allied extinct chambered Cephalopods adds demonstrative proof, were such required, of the accuracy of Dr. Buckland's negation, whilst the association of the spathose guards with crushed phragmocones, identical in structure with those in connection with the fossil ink-bag and muscular parts of the specimens under consideration, and all from the same

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* Pl. IV. fig. 2.

† Pl. V.

‡ Pl. IV. fig. 1.

§ Near the confused remains of the head in this specimen there is the impression of part of the phragmocone of another Belemnite.

‖ Philosophical Magazine, 1829.

Fig: 2.

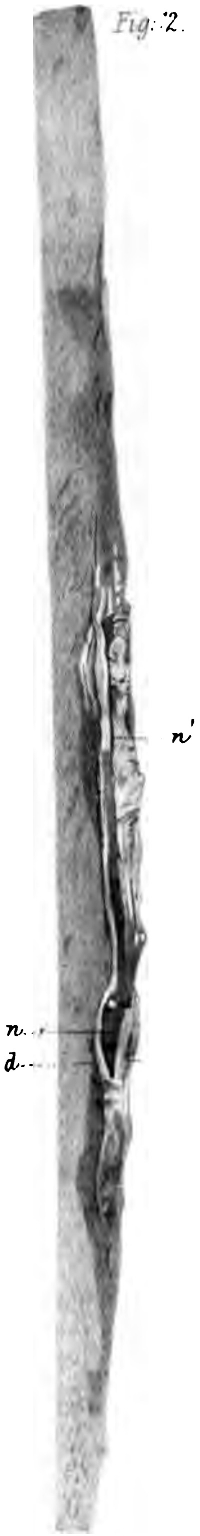
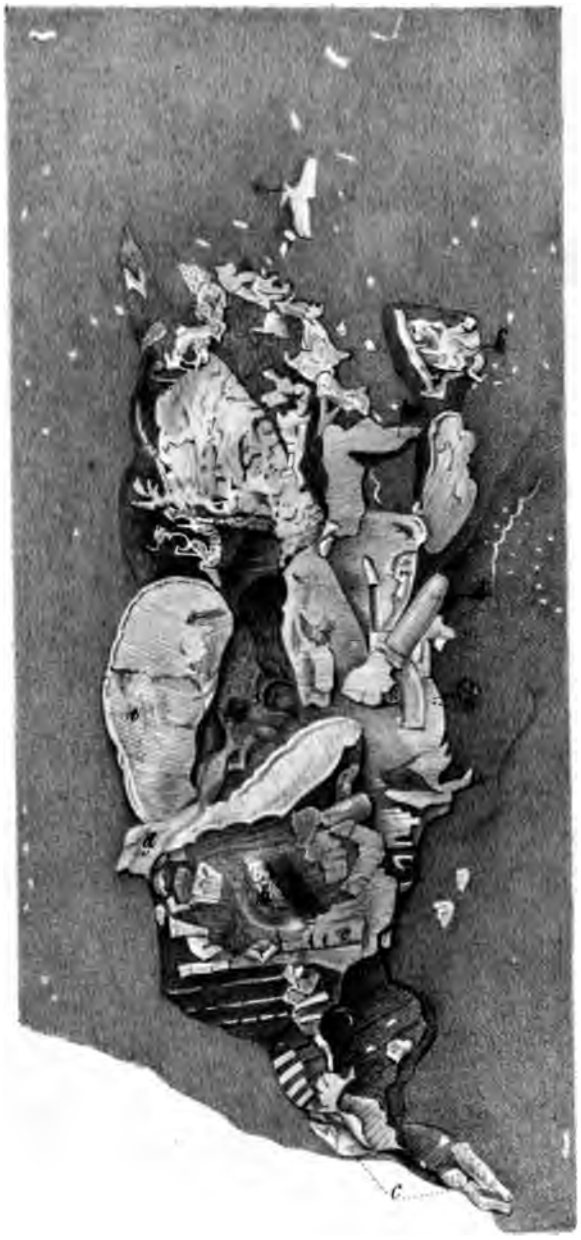


Fig: 1



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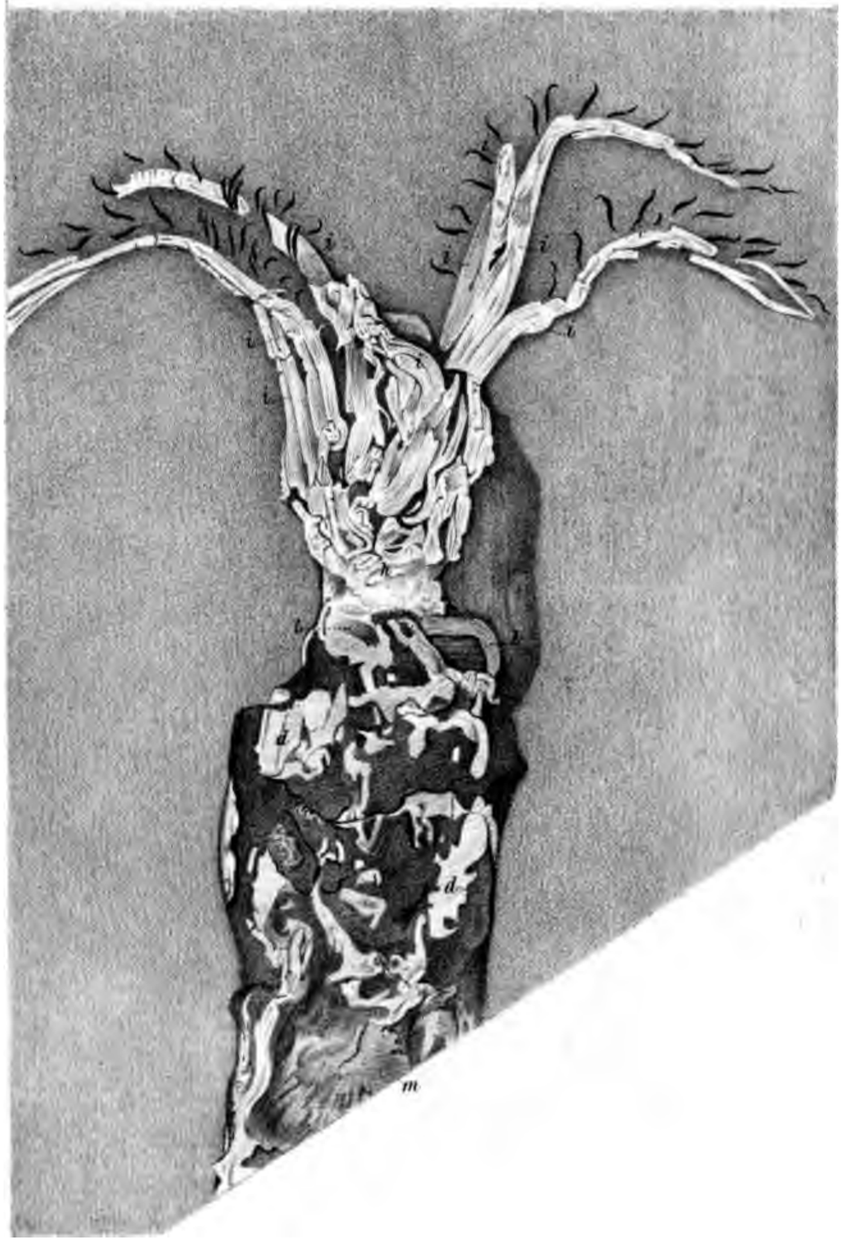

J. Basire, Zinc

stratum and restricted locality, admits of no reasonable doubt of their belonging to one and the same species of true Belemnite.

The two flattened fibrous bodies, (*e*, *e*) with well-defined semi-oval external and apparently free margins,—the one on the right side entire, the one on the left having the contour of the defective part of the margin indicated by the dark carbonaceous stain in the matrix,—are the parts which I regard as the lateral fins of the mantle. They have been slightly displaced transversely and pressed inwards upon the yielding viscera; their original cartilaginous basis would favour their encroaching in that direction if subjected to equable surrounding pressure: the lateral fin which is preserved in the first specimen* has been pushed more deeply inwards.

The large end of the semi-oval free border is the anterior one, where the fin is broadest; it gradually becomes narrower posteriorly. The muscular fasciculi are strongly marked, and are arranged transversely to the long axis of the fin, as in existing Decapodous Cephalopods. It is interesting to find a rounded contour associated with an advanced position of the lateral fins in the ancient Belemnites, as in the modern *Rossia* and *Sepiola*, the rhomboidal form being most common in those fins which are placed at the end of the body, as in the Onychoteuthis and Loligo; the only exception, indeed, being presented by the *Loligopsis*, which has terminal and rounded fins.

M. Duval, the latest and most accurate author on fossil Belemnites, reproduces† the figure which M. D'Orbigny has published, and which is essentially the same as that given by Dr. Buckland in his Bridgewater Treatise; and, like it, differs from Mr. Miller's restoration, in the position of the ink-bag and in the extended state of the terminal fins. With respect to these parts, M. Duval, from his discovery of the united fractures of the spathose guard, has objected with much acumen, that, if the fins of the Belemnite had been placed at the side of the guard, they must have been rendered useless by its fracture, and the creature, thus deprived of its power of swimming, would soon have fallen a prey to its numerous enemies, and would not have survived to exemplify the reparative powers of those ancient Cephalopods. M. Duval, however, modestly concludes by confessing that he should not have dared himself to figure from the known analogies, the animal to which the Belemnite ought to have belonged; for "I have not," he says, "a sufficiently exact knowledge of the organic laws of the Cephalopoda." It seemed vain to hope that the soundness of the principles on which the classification of the Belemnites with the dibranchiate Cephalopods had been definitely proposed, should ever be vindicated by the demonstration of parts, apparently so perishable as the fleshy mantle, the fins, and the slender flexile arms of these ancient Mollusca‡.

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* Pl. III.

† Sur les Belemnites, 4to, Pl. 7. fig. 10.

‡ Cuvier, in the second edition of the 'Règne Animal,' places the *Belemnites* between the *Orthoceratites* and the *Ammonites*, and observes, "*ils appartiennent probablement encore à cette famille, mais il est impossible de s'en assurer, puisqu'on ne les trouve plus que parmi les fossiles,*" tome iii. p. 19,—which teaches how liable the best authorities are to err, when they would set bounds to the possibilities in Nature.

But we derive from the present remarkable specimens ample confirmation of the association of the ink-bag with the higher grade of the circulating and respiratory organs, which grade is necessarily associated with the high development of the locomotive system, as demonstrated by the muscular mantle and its appended fins; whilst the preservation of the latter organs *in situ* establishes the soundness of M. DUVAL's objections to their position in all the published conjectural restorations of the Belemnite.

In the specimen under consideration[*] the fins are crossed by a narrow tract of grey transversely fibrous substance, probably part of the mantle, near the anterior termination of which an oblong flattened tract of similar substance extends forward, slightly expanding as it advances to a position opposite the neck of the Belemnite, where it is terminated by a slightly concave truncation: longitudinal fibres may be discovered decussating the more abundant transverse fibres of the part which is most probably the remains of the infundibulum. A short flattened band of fibres (*g*) connects this part with the neck of the Belemnite, having the exact position and proportion of the retractor or levator muscles of the infundibulum of the naked Cephalopods[†]. The traces of muscular tissue in the situation of the head are much more obscure: two short processes from the anterior part of this mass are evidently the bases of tentacula or cephalic arms.

At the middle of the visceral mass, in the interval of the two lateral fins, there lies a compressed body of a horny texture and sub-bilobed form (*m*), on which may be clearly distinguished striæ passing outwards in opposite directions from a middle line and diverging from each other in their course, which resembles that of the fibres of the digastric muscle in the gizzards of the Nautilus and other Cephalopods: this apparent remnant of the stomach lies about half an inch in advance of the ink-bladder, in a position corresponding with that of the gastric organ in naked Cephalopods.

There is strong negative evidence that the Belemnite possessed horny mandibles like the other naked Cephalopods, since no calcareous beaks, or Rhyncholites, have been discovered associated with the specimens from the Oxford clay, or with those from the lias.

The thickness of the layer of dried and compressed grey fibrous matter to which the mantle is reduced is half a line, and we may infer from this, that in its soft and recent state, when permeated by its sanguiferous vessels, it must have equalled in thickness that of a Calamary of the same size. In fact the mantle of true *Teuthidæ* (Calamaries with horny pens), preserved in the same matrix as the Belemnites here described, has been reduced to a compact fibrous layer of the same thinness: a specimen of one of these[‡] displays by a fracture of the layer of the clay in which it was imbedded, the anterior and posterior walls with the intervening cavity of the abdomen, exposing the ink-bag and duct *in situ*.

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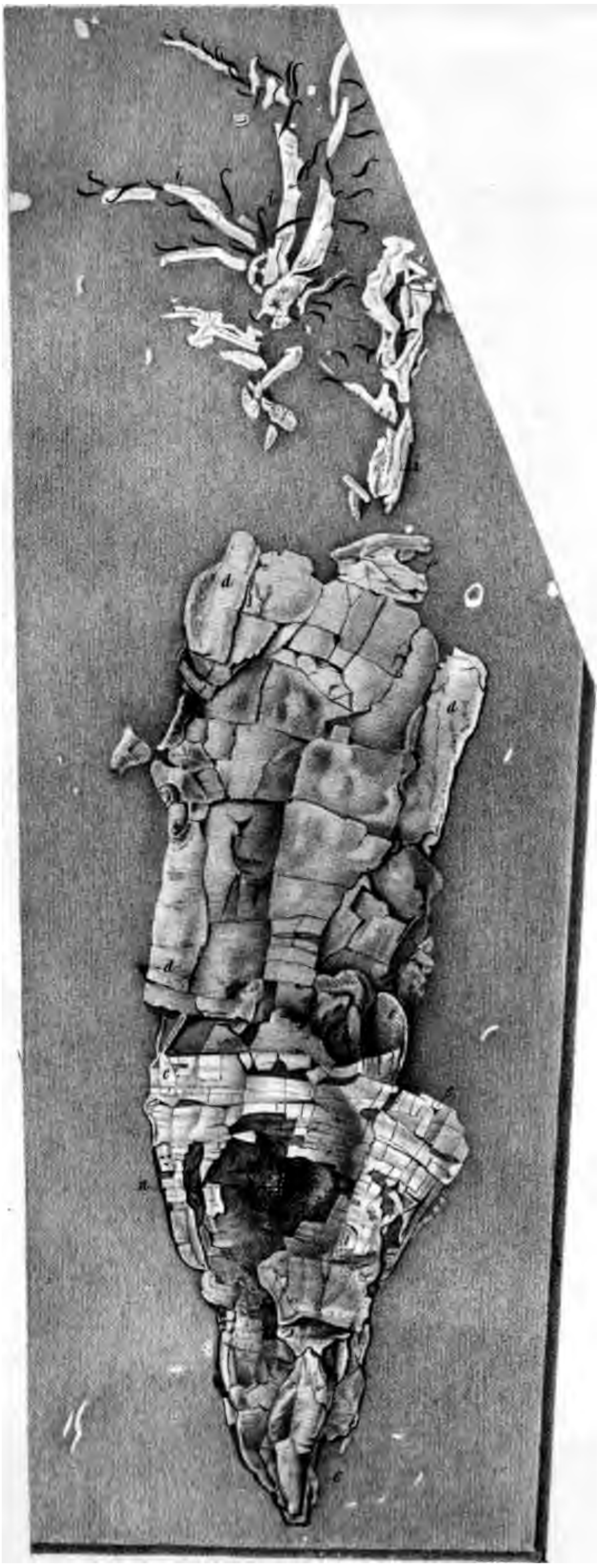
[*] Pl. IV. fig. 1.

[†] Compare fig. 10, *g*, with CUVIER's Pl. 1. fig. 2, *m*, *n*, Mémoire sur le Poulpe, 4to.

[‡] Pl. IV. fig. 2.



J. Basire, Zincog.

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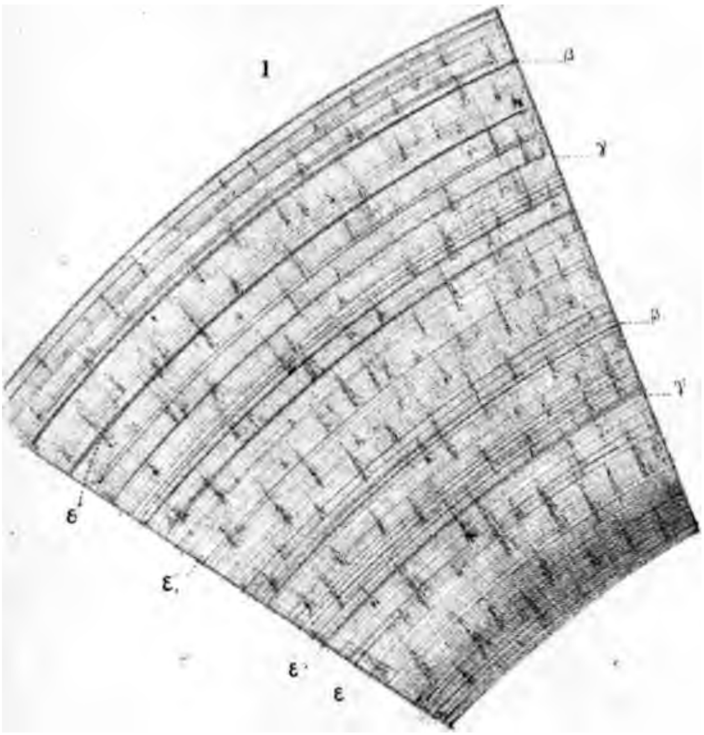

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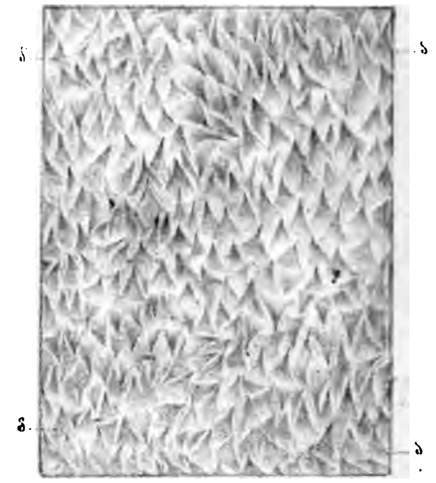

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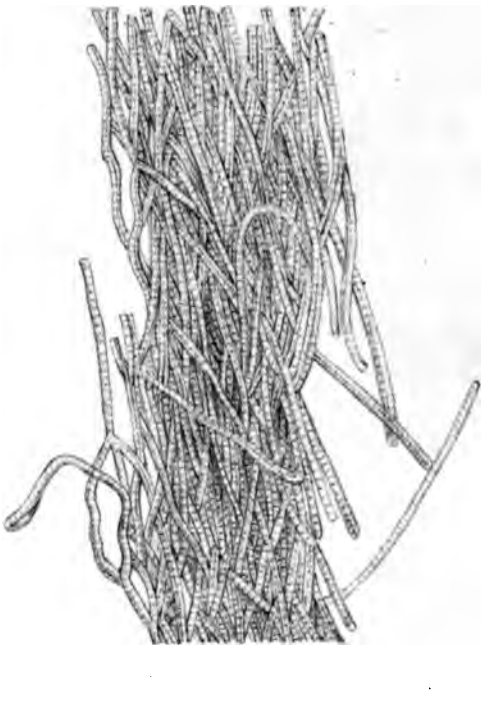

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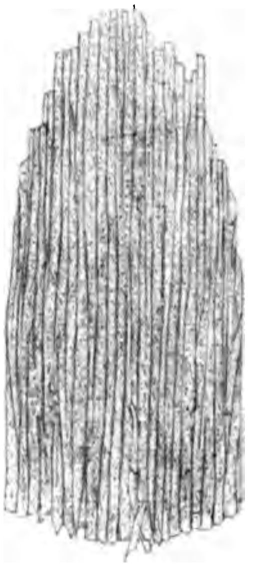

Lens Aldous, del. et Zinc.

J. Basire,

Microscopic structure of the guard and Muscular fibre.

In neither of the above described specimens of Belemnite having the soft parts and phragmocone in natural connections, is there any evidence of the muscular part of the mantle having been continued over the capsule of the phragmocone; it is traceable for a short way below the peristome in Mr. CUNNINGTON's specimen*; but it is best developed where it surrounded the compressible part of the body of the Belemnite anterior to the shell. There seems no reason, however, to doubt that the skin, which, in existing naked Cephalopods is thin and lubricous, and more easily detached from the subjacent muscular layer than in the lower Mollusks, was extended over that part of the phragmocone extending beyond the alveolus, as there has been already shown evidence of its continuation over the alveolar and solid part of the spathose guard: its gelatinous base was less favourable for preservation than the fibrinous nature of the muscular tunic, and its destruction is, therefore, not surprising. The dark stain upon the clayey matrix, which usually extends a little beyond the preserved muscular structure, may in part be due to the pigmental cells of the skin; and these seem evidently to have produced the thin crust of a dark greenish colour which hides part of the fibrous layer of the mantle in the third specimen left for description.

This†, which is from the collection of Mr. PRATT, is chiefly remarkable and valuable for the perfect conservation of the complex muscular structures of the head and its uncinated arms. Eight of these, forming the normal series of cephalic arms, may be defined, radiating from a contracted base. In this base may be observed two decussating groups of curved fibres (*h*), the posterior one with its concavity turned towards the mantle, the anterior one with its concavity directed forwards, and its horns continued into the bases of the arms. A similar decussated arrangement of fibres exists in the *Onychoteuthis*, and is described and figured by CUVIER in the corresponding part of the head of the *Octopus*. Almost the entire extent of five of the cephalic arms is preserved, as shown in the figure; they are rather longer in comparison with the mantle than in the modern Onychoteuthis, but not as compared with the entire body of the Belemnite when this is lengthened out by the terminal spathose guard: the longitudinal arrangement of the fasciculi of muscular fibres of the arms is very distinct.

I placed a portion of the muscular tissue under the microscope, and succeeded by the aid of a drop of diluted acetic acid in softening and unravelling the constituent fibres‡; they presented the same size as the fibres from the corresponding part of one of the arms of an *Onychoteuthis*, but the faint transverse striæ visible in the recent fibre§ had disappeared in the fossil, and only an obscure granular structure could be discerned.

Each of the arms seems to have been provided with from fifteen to twenty pairs of hooks‖, which were doubtless developed from the horny hoops which encircled the caruncles of the acetabula, as in the modern *Onychoteuthis*.

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* Pl. VI. fig. 1, *d*. † Pl. V. ‡ Pl. VII. fig. 4. § Ib. fig. 3.

‖ Pl. VI. fig. 2, is a magnified view of the most perfect of these hooks.

Two small protuberances at the origin of the normal brachia are the only parts which represent the bases of the pair of long tentacula, superadded to the eight shorter arms in the existing *Decapoda*.

On each side of the head, behind the bases of the arms, there is a convex protuberance formed by a well-defined semicircular band, about a line in thickness, of grey fibrous matter, the fibres or layers being parallel with the curve of the band. These parts are more distinctly shown in Mr. CUNNINGTON'S specimen, in the description of which the reasons for regarding them as belonging to organs of vision are given. In the present specimen they indicate, according to this view of their nature, that the eye-balls of the Belemnite were sessile*, and agreed in size, as in position, with those of the modern naked Cephalopods.

Another specimen of similar size, in the collection of Mr. PRATT, exhibits the upper two-thirds of the visceral cavity formed by the mantle and the head with the bases of the arms, one of which is preserved to the extent of two inches, another to that of one inch, and on both these a few of the horny hooks remain. At the lower part of the head a circular amorphous granular mass is visible; it is bounded anteriorly by a curved fasciculus of fibres with the concavity directed backwards: above these the fibres which are continued into the bases of the arms commence from a fasciculus curving in a direction opposite to the preceding. These decussating bands are similar to thoſe in the former specimen but are more strongly marked. The fibres continued into the arms are chiefly longitudinal. The few hooks which are preserved in this specimen are identical in size and shape with the more perfect series in the preceding specimen.

There is a minute trace on the left side, near the lower end of the specimen, of an obliquely striated horny plate. Most of the preserved fibrous structure of the flattened mantle is transversely arranged, as in all the other specimens; but a faint trace of longitudinal or retractile fibres may be discerned near the anterior margin of the mantle.

The fracture of the slabs of clay containing the last two instructive specimens has crossed obliquely that part of the abdomen in which is situated the striated thin horny plate, agreeing with that which I have ascribed to the gizzard: wanting therefore both the ink-bag and phragmocone, these specimens were defective in the requisite evidence to associate the uncinated arms with the complex shell, muscular mantle, and rounded fins of the Belemnites.

The coexistence with the true Belemnites, in the Oxford clay at Christian-Malford, of fossil Calamaries with a dorsal horny gladius or pen, like those from the lias at Lyme Regis described by Dr. BUCKLAND†, made it still more desirable to obtain such evidence as could only be given by more entire specimens of those ancient uncinated Cephalopods than those above described from the collection of Mr. PRATT, which were the first and for some time the only specimens of the kind that I had seen.

The subsequent fortunate discovery of the unique example‡ submitted to my ex-

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* In the *Nautilus* the eyes are pedunculated.

† Bridgewater Treatise, i. p. 308.

‡ Pl. III.

Fig: 1.

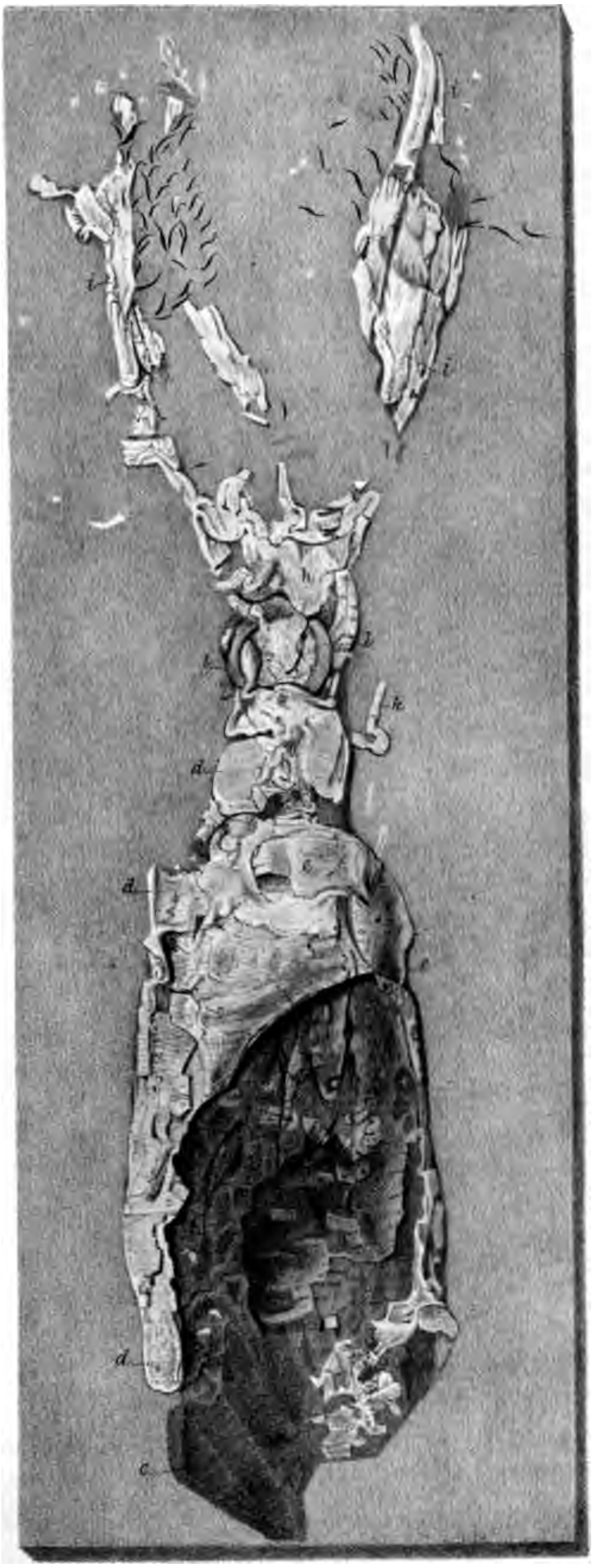


Fig: 3.

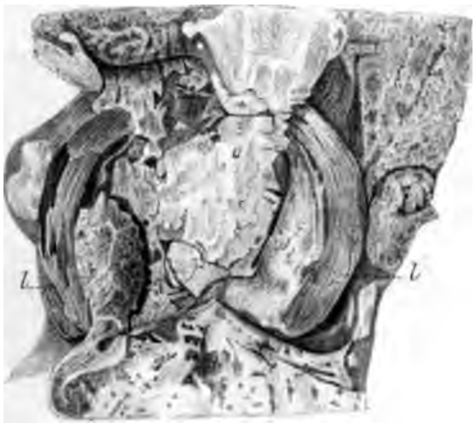
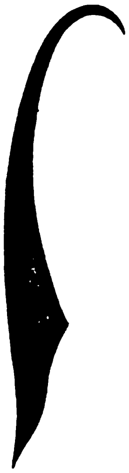


Fig: 2.



J. Basire sc.

amination by the noble President gave the much-desired solution to the question; the form of the muscular part of the mantle, the proportions of the arms, and the number, shape and disposition of the horny hooks, being identical in that specimen of the Belemnite with those in the beautiful one with the crown of uncinated tentacles formerly in Mr. Pratt's cabinet, and now deposited, with the more perfect Belemnite from Lord Northampton's collection, in the Hunterian Museum.

I have more lately been favoured by Mr. Cunnington of Devizes with the temporary possession of the instructive specimen* of the *Belemnites Owenii* obtained from the same stratum and locality as the foregoing. It exhibits a considerable proportion of six of the cephalic arms; one of them is three inches and a half in length, but not entire; a full inch of another is indicated or represented by the double series of hooks, in their natural relative position, there being ten pairs in this extent.

The muscular tissue, forming the common base of the arms (*h*), has been preserved in a more compact mass than in Mr. Pratt's specimen, but the arrangement of the fibres is distinguishable. A median fine groove may be traced along each of the best preserved arms, indicating the cavity in which the artery and nerve were lodged.

From near the side of the common uniting base of the ordinary uncinated arms a long and narrow tract of fibrous matter (*k*) bends down along the side of the head to the beginning of the mantle, becomes more slender than the cephalic arms, and is reflected, with an irregular twist, forwards again; this is obviously the basal part of one of the long superadded tentacles.

The most marked and peculiar character of the present specimen is seen in the part of the head immediately behind the base of the arms; at this part, imbedded in the usual grey remains of the muscular tissue, are two semicircular portions of a denser and darker greyish brown fibrous substance (*l l*), obviously the same parts as those above described and referred to the eyes, in Mr. Pratt's second specimen†; the parts in question are regularly placed in reference to each other in the present specimen, being on the same transverse line, with their concavities towards each other, and their convexities turned outwards: each body is a line in breadth and does not diminish at either extremity, which is lost in or hidden by the surrounding muscular tissue: their structure is more minutely but more definitely fibrous than in the muscles, the fibres following the curve of the band. The parts in existing Cephalopods, which first suggest themselves for comparison with these, are, the beak, the cartilage of the head, the cornea or the crystalline lens. The position of the curved fibrous bodies is posterior to that in which the beak should be placed, agreeably with existing analogies; the texture of the beak, also, in the *Onychoteuthis* is the same as that of the hooks, whilst that of the parts in question is very different from the black horny matter of the preserved hooks. The position of the parts in the present specimen, like that in Mr. Pratt's, corresponds with that of the large sessile eyes, only that they are more nearly approximated towards each other. In reference to the large crystalline lens which characterizes the eye in naked Cephalopods, the parts in question can only be compared, from their size, with the exterior laminæ of the outer division of the lens, in which case the larger and denser inner division of the lens has not at all been preserved; which is by no means a probable occurrence, and induces me to reject this analogy. If we compare them to the strong external tunic of the eye, their outward convexity would lead to their being referred to the cornea. But this part, in all existing Cephalopods is a modification of the integument, and continuous with it, presenting a less degree of convexity than in the fossils, less thickness, and a less definite extent. Viewing, however, the relative position, form and structure of the parts under consideration in the two specimens in which they are preserved, the most probable conclusion respecting their nature appears to me to be that which refers them to the anterior or external tunic of the eye-ball, in which case they indicate a thicker, stronger, more distinct, more extensive, and more convex cornea in the Belemnite than in any known existing Cephalopods.

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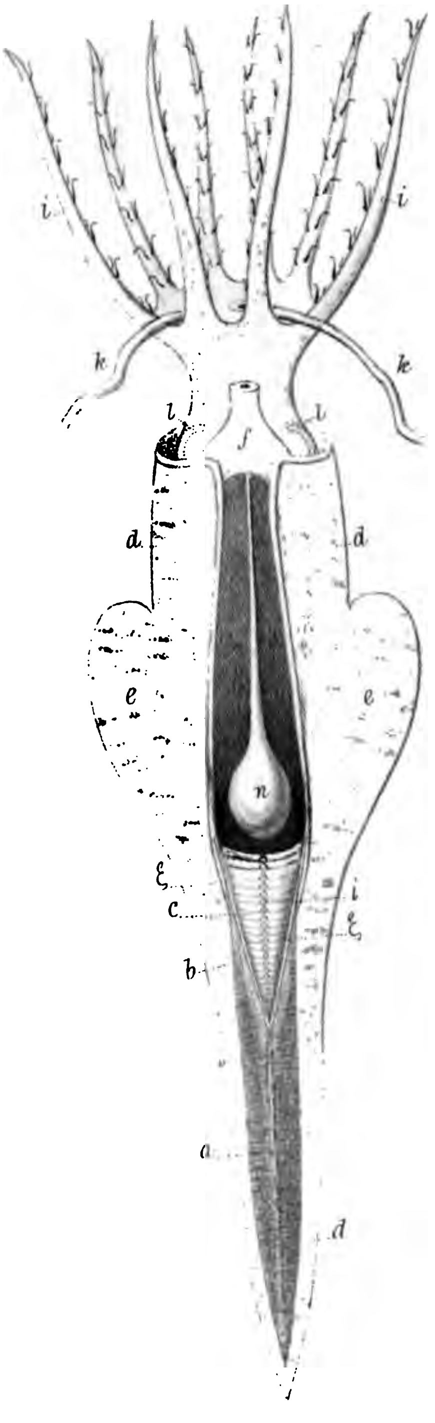
* Pl. VI. fig. 1.

† Pl. V.

Just behind the eyes is an oblong body in which a fine longitudinal arrangement of fibres is visible; this may be the remains of the funnel: in the adjoining part of the mantle the transverse fasciculi are, as in the other specimens, plainly discernible. The left fin (*e*) is well preserved, and the contour of part of the right fin, as it seems to me, is traceable, folded back upon the mantle. The left fin presents exactly the same relative size and semi-oval contour of the free margin which is shown in Mr. PRATT's specimen; it has been slightly displaced, and advanced obliquely near the anterior border of the mantle. A very compact shining dark-coloured substance at the detached basal margin of this fin may be the charred remains of its supporting cartilage. The right fin, the free border of which is bent inwards upon the mantle, as is not unusually seen in ordinary naked Cephalopods, has preserved its true position, rising a little above the visceral chamber of the phragmocone. The most important additional fact which we derive from the present specimen is the continuation of the mantle over the sheath of the phragmocone, proving indisputably the internal position of that part. The chambered division and thin calcareous and nacreous structure of the crushed remains of the phragmocone are quite identical with those of the phragmocones preserved with the spathose guard in the specimens from Mr. PRATT's and Mr. BRODERIP's cabinets.

In the present specimen about one inch of the apex of the phragmocone has been separated from the rest, but its impression is distinctly preserved: in this we may trace the longitudinal fold of the crushed capsule, and the impressions of the chambers and septa to within a few lines of the apex. At the anterior part of the phragmocone we have the depression in which the ink-bag with its indurated contents was lodged. Remains of a thin horny plate are situated anterior to the ink-bag.

The evidence afforded by the above-described specimens of the paucity in number and superiority in size and complication of the cephalic tentacles of the Belemnite,



Belemnite restored

as compared with those of the Nautilus, yields another proof of the constancy of the laws of organic correlation; the very numerous, small, and comparatively simple tentacula of the Nautilus, which illustrate the principle of vegetative or irrelative repetition, being associated with an essentially inferior type of Cephalopodal organization, into which an internal shell, a thick muscular mantle, pallial fins, and an ink-secreting apparatus do not enter.

The cephalic arms of the existing species of Onychoteuthis present at the present day the highest grade of organization that has been observed in these characteristic prehensile instruments of the Cephalopoda. The great specimen captured by BANKS and SOLANDER off Cape Horn in the first voyage of Captain COOK, offers the best example of this formidable prehensile structure, since, not only were the extremities of the two long tentacula beset with hooks, but all the eight normal arms supported a double alternate series of uncinated acetabula.

But in comparing the different forms of Cephalopods that have successively appeared and perished since the deposition of the lias to the present time, we do not find that the above most complex organization of the cephalic arms has been attained by or through progressive gradations, typified by the organization of intermediate forms: the ancient Belemnites manifested the uncinated armature as perfectly as the most formidable of existing *Onychoteuthides*. Nor were true Calamaries, with uncinated arms, absent in those primeval seas, which were tenanted by living Belemnites, Ammonites, and other extinct forms of Cephalopoda. The existence of naked Cephalopods of the family *Teuthidæ* in the oolitic secondary formations, has been for some years demonstrated by the well-preserved and recognizable remains of the ink-bag, the gladius or horny pen, and the horny hooks developed from the acetabula of the cephalic arms.

These singular fossils have been elucidated by the minute and accurate descriptions of Dr. BUCKLAND[*], and have elicited some beautiful remarks from the same eloquent writer in his Bridgewater Treatise[†]. They have been noticed and described by ZEITEN, by V. MEYER, and Count MUNSTER, from the lias schale of Aalen and Boll, and from the Solenhofen slate. The impression of an entire Onychoteuthis with the double series of hooks belonging to the eight short arms, nearly in their natural position, is figured in the Sixth Livraison of M. D'ORBIGNY's 'Paléontologie Française,' 8vo, now in course of publication, under the name of *Celæno speciosa*, assigned to it by Count MUNSTER. These hooks very closely resemble those of the *Belemnites Owenii*, but their base is rather less recurved, and they are more closely arranged: the fleshy part of the arms is not preserved; but they were evidently shorter in proportion to the mantle than in the Belemnite.

In conclusion, if we compare the Belemnite as now restored[‡], not conjecturally, but by observation of phenomena, with the known existing forms of the Dibranchiate or higher order of Cephalopods, in which its right of place can no longer be disputed, we shall first recognize in the outwardly concave plates and margino-ventral siphon of the chambered shell of the Spirula, the analogue of the hydrostatic part of the shell or phragmocone of the Belemnite: next in reference to the entire shell we must admit, agreeably with the opinion of DE LUC, MILLER, DE BLAINVILLE and BUCKLAND, that the *Sepia* or common Cuttle Fish, most nearly resembles the Belemnite in the general structure and position of its complex calcareous plate. The nucleus or terminal spine of the sepium or cuttle bone corresponds with the terminal spathose guard of the Belemnite; the convex posterior broad plate of horny with friable calcareous matter is analogous to the capsule of the phragmocone; but its margins, instead of being approximated and soldered together, are free and lateral in position: the congeries of transverse plates, lodged in the concavity of the nucleus and of the foregoing semi-capsule of the cuttle-bone, answer to the chambered phragmocone of the Belemnite, but, instead of being perforated by one or many siphons, they are entire and connected with each other by a series of minute undulating lamellæ perpendicular to their plane.

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[*] Proceedings of the Geological Society, 1829.

[†] Vol. i. p. 303.

[‡] Pl. VIII.

The lateral fins of the Sepia are narrow, and extend, as is well known, from the apex of the mantle to near its base; while the fins of the Belemnite were relatively shorter and broader, and situated a little in advance of the middle of the body. In the relative size, shape, and position of the fins, the Belemnite must have most nearly resembled the species of the existing genera *Rossia* and *Sepiola*, but it differed in the more elongated and slender body.

The character of the formidable hooks, supported by the acetabula of the arms, is now exclusively manifested by the genus *Onychoteuthis*.

Thus the extinct Belemnite combined characters at present divided amongst four distinct genera of Dibranchiate Cephalopods, *Spirula, Sepia, Sepiola*, and *Onychoteuthis*. But, notwithstanding the uncinated character of the arms, the balance of its natural affinities seems to me still to preponderate in favour of its position as a transitional link between *Spirula* and *Sepia*: and the additional facts which we have now unexpectedly gained, while they show new and unsuspected radiations of affinity tending to complete the reticular interdependencies of the Cephalopods, do not disturb, but confirm the position of the Belemnite, in the linear series of the genera of that class which I proposed in 1836.

The Belemnite, with the advantage of its dart-shaped and well-balanced shell, must have enjoyed the power of swimming backwards and forwards by the action of its cephalic and pallial fins, with greater vigour and precision than the modern Decapod *Dibranchiata*. The position of the animal was, most probably, more habitually vertical than that of its recent congeners. Thus placed, the Belemnite, in quest of prey, would rise swiftly or stealthily to infix its claws in the belly of a supernatant fish, and then dart down, and drag its prey to the bottom and devour it. And we cannot doubt, but that, like the uncinated Calamaries of the present seas, the ancient Belemnites and their associates, the Celænos, were, in their day, the most formidable and predaceous of Cephalopods.

We admire the skill of the Egyptian embalmers, which has enabled CUVIER[*] to test the influence of time in transmuting specific forms, by a comparison of the *Ibis* of the present century with one that died 3000 years ago. The researches of the chemist may afford an insight into those properties of the soil, in which the above described valuable and instructive specimens of Cephalopoda were entombed, that favoured the apparent conversion of their muscular tissue into adipocire, and its subsequent preservation to the present day. I can only describe this conservative matrix as a peculiarly fine and compact, but fissile, laminated variety of the Oxford clay: a formation at the base of the great middle oolitic system, more ancient than the Portland stone, the Wealden and the entire Cretaceous group. The Cephalopods in which we may now study the microscopic character of the muscular fibre, must therefore have existed at a period antecedent to the gradual deposition of these enormous masses of the secondary strata, which themselves preceded the formation of the entire tertiary series, and the overspreading unstratified masses, called diluvial. The attempt to conceive or calculate the period of time which must have elapsed since the Belemnites were thus embalmed, baffles and awes the imagination.

DESCRIPTION OF THE PLATES.

All the figures are of the same species of Belemnite (*Bel. Owenii*, PRATT), and of the natural size, except where otherwise indicated.

The following letters indicate the same parts in each figure.

a. The guard.
b. The alveolus or socket of the guard for lodging,—
c. The phragmocone; *ζ*, the sheath; *θ*, septum; *ι*, siphon.
d. Muscular tunic of the mantle; *η*, fold of the sheath.
e. The pallial fins.
f. The infundibulum.
g. The levatores infundibuli.
h. Decussating muscular fibres of the head.
i. The uncinated arms.
k. The tentacula.
l. The eyes (?).
m. The lining or muscular tunic of the stomach.
n. The ink-bag.

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[*] Discours Préliminaire sur les Révolutions du Globe, Ossemens Fossiles, tom. i. p. 141.

PLATE II.

Fig. 1. Spathose guard and crushed phragmocone of a *Belemnites Owenii*.
Fig. 2. Apical extremity of the guard, showing the ventral groove *α*, and the form of the transverse section above the groove.
Fig. 3. A transverse section of the guard through the alveolus, showing one of the partitions of the phragmocone.
Fig. 4. The guard of an embryo Belemnite.
Fig. 5. The guard of a young Belemnite, in the condition of an *Actinocamax*.
Fig. 6. A detached and crushed phragmocone, showing the folds of the capsule at *η*.
Fig. 7. A detached and crushed phragmocone in its capsule, *η*, with one of the partitions, slipped forwards, *θ*.
Fig. 8. A detached partition from near the base of the phragmocone.

PLATE III.

The specimen of *Belemnites Owenii*, from the Oxford clay, from the collection of the Marquess of Northampton, P.R.S., showing the phragmocone, muscular mantle, and portions of the fleshy arms, preserved in their natural relative positions.

PLATE IV.

Fig. 1. The specimen from the collection of S. P. Pratt, Esq., F.R.S., showing the phragmocone, part of the muscular mantle, lateral fins and funnel.
  c. The apex of the crushed and disturbed phragmocone.
  d. Portions of the transverse muscular tunic of the mantle.
  e, *e*. The two lateral fins: that on the right side is entire.
  f. The remains of the infundibulum.
  g. The levator muscles of the infundibulum.
  m. The striated horny plate ascribed to the gizzard.
  n. The remains of the ink-bag.
Fig. 2. Section of an embalmed Calamary (*Celæno*, Munster).

PLATE V.

The specimen from the collection of S. P. Pratt, Esq., F.R.S., showing the muscular mantle, head, and uncinated arms.

d. Portions of the transversely fibrous coat of the mantle, obscured in many parts by apparently the remains of the pigmental coat of the skin.
i. The uncinated arms.
l. The remains of the eyes.
m. The striated horny plate ascribed to the gizzard.

PLATE VI.

Fig. 1. The specimen from the collection of William Cunnington, Esq.
Fig. 2. A magnified view of one of the horny hooks.
Fig. 3. A magnified view of part of the head with the fibrous bodies supposed to belong to the eyes.

PLATE VII.

Highly magnified views of the spathose and muscular textures of the Belemnite.

Fig. 1. A portion of a transverse section of the fibrous guard.
  γ. The lines indicating the prismatic fibres.
  β. The lines indicating the layers of growth.
  ι. The triangular specks produced by abrasion of the surface.
Fig. 2. Longitudinal section of the fibrous guard, across the prismatic fibres, δ.
Fig. 3. Primitive muscular fibres of the *Onychoteuthis Banksii*, showing transverse striæ, similarly magnified.
Fig. 4. Primitive muscular fibres of the *Belemnites Owenii* magnified 600 diameters, linear.

PLATE VIII.

Restoration of the Belemnite, according to the structures observed in the specimens preserved in the Oxford clay at Christian-Malford.

The same letters indicate the same parts as in the foregoing figures.

d. The continuation of the mantle over the phragmocone and guard of the internal shell of the Belemnite.

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OF

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ADJUDICATION of the MEDALS of the ROYAL SOCIETY for the year 1844 by the PRESIDENT and COUNCIL.

The **COPLEY MEDAL** to Professor C. **MATTEUCCI** of Pisa, for his various researches in Animal Electricity.

The **ROYAL MEDAL**, in the department of Mathematics, to **GEORGE BOOLE**, Esq., for his Paper entitled "On a general method in Analysis," published in the Philosophical Transactions for 1844.

The **ROYAL MEDAL**, in the department of Chemistry, to **THOMAS ANDREWS**, M.D., for his Paper entitled "On the thermal changes accompanying Basic Substitutions," published in the Philosophical Transactions for 1844.

The Paper appointed for the Bakerian Lecture in 1844, is Professor **OWEN**'s, entitled "A description of certain Belemnites, preserved, with a great proportion of their soft parts, in the Oxford clay, at Christian-Malford, Wilts."

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APPENDIX.

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PHILOSOPHICAL TRANSACTIONS.

VII. *Contributions to Terrestrial Magnetism.—No. VI.*

By Lieut.-Colonel EDWARD SABINE, *R.A., F.R.S.*

Received April 17,—Read April 18, 1844.

§ 10. *Observations made on Board Her Majesty's Ships Erebus and Terror, from June* 1841 *to August* 1842, *in the Antarctic Expedition under the command of Captain Sir* JAMES CLARK ROSS, *R.N., F.R.S.*

I HAVE now to lay before the Royal Society the results of the Magnetic Observations made at sea by the Antarctic Expedition during the second year of its operations in the southern hemisphere. Leaving Hobarton early in July 1841, the ships proceeded in the first instance to Sydney in Australia, and from thence to the Bay of Islands in New Zealand, where they remained until the return of the season of navigation in the high latitudes. Quitting New Zealand in November, the ice was met with and entered in a somewhat lower latitude than in the preceding year, and in a longitude considerably to the east of the former track. The obstacles which the ice presented to their progress appear to have been greater than on the former occasion; they were however surmounted, and in February 1842 the ships again reached the ice barrier, or glacier, in latitude 78°, by which they had been stopped in the preceding year. After an unsuccessful endeavour to turn the eastern extremity of the glacier, the advance of the season compelled their return to the lower latitudes; they quitted the Antarctic Circle in March 1842, and keeping nearly in the 60th parallel, crossed the whole breadth of the southern Pacific Ocean to the Falkland Islands, where they arrived in April.

I proceed at once to the examination in detail of the magnetic observations made during this period.

Deductions of the Constants a and b in the Corrections for the Ship's attraction.

1. *In the Erebus.*—For the constants a and b to be employed in computing the corrections of the declination, we have the observations on each of the 32 principal points of the compass at Hobarton, in October 1840 and June 1841. We have also a similar series at Port Louis, in the Falkland Islands, in August 1842. The observations at Hobarton have been already discussed in No. V.* Those at Port Louis were as follows:—

August 19, 1842.

Ship's head by compass.	Disturbance towards the west.	Ship's head by compass.	Disturbance towards the west.	Ship's head by compass.	Disturbance towards the west.	Ship's head by compass.	Disturbance towards the west.
	° ′		° ′		° ′		° ′
N.	+0 12·7	W.	−2 15·8	S.	+0 00·1	E.	+2 07·4
N. by W.	−0 04·1	W. by S.	−2 21·2	S. by E.	+0 43·9	E. by N.	+1 54·0
N.N.W.	−0 33·6	W.S.W.	−2 21·3	S.S.E.	+1 12·7	E.N.E.	+1 44·0
N.W. by N.	−0 50·1	S.W. by W.	−2 4·3	S.E. by S.	+1 41·4	N.E. by E.	+1 16·5
N.W.	−1 02·3	S.W.	−1 8·0	S.E.	+1 55·5	N.E.	+0 50·9
N.W. by W.	−1 00·6	S.W. by S.	−1 3·3	S.E. by E.	+2 06·9	N.E. by N.	+0 40·5
W.N.W.	−1 49·3	S.S.W.	−1 17·3	E.S.E.	+2 18·9	N.N.E.	+0 41·2
W. by N.	−2 09·6	S. by W.	−0 38·6	E. by S.	+2 16·4	N. by E.	+0 27·7

The values of the constants deduced from the observations at Hobarton were, $a=+{\cdot}0272$; $b=+{\cdot}986$. The values from the observations at the Falkland Islands are, $a=+{\cdot}0292$; $b=+{\cdot}984$.

The values of a at Hobarton were derived from two series, one in October 1840, when the ship had recently passed through the low magnetic latitudes, and the other in June 1841, on her return from the highest magnetic latitudes of the southern hemisphere; the two series separately considered give $a=+{\cdot}0235$ in 1840, and ·0309 in 1841; we have therefore the following values:—

+·0267 in the Thames, where the ship had been stationary for several years.

+·0235 at Hobarton, on her first arrival from the low latitudes.

+·0305 on her return to Hobarton from the very high southern magnetic latitudes.

+·0292 at the Falkland Islands in 1842, on her second return from the very high southern latitudes.

The variations in these values is in accordance with the view expressed in the preceding Number of these Contributions†, that when a ship changes her magnetic latitude, the corresponding change in the induced portion of her magnetism may not be instantaneous; that some portions of her iron may be of a quality intermediate between perfectly soft iron, which would undergo instantaneous change, and iron permanently magnetic; and that when changing rapidly her geographical position, she may be liable to be more or less in arrear, in regard to her magnetic condition, of her actual locality at any particular time. In a ship in which this should be the case, a table computed with any one value of a would not apply equally to one portion of her voyage in which she might be sailing from lower into higher inclinations, and to another portion in which she might be returning from higher into lower magnetic latitudes. The voyage under consideration comprised two such portions; and I have therefore employed two tables for the Erebus, one computed with ·0267 for the period when the ship was increasing the dip, and the other with ·0288 for the period when she was decreasing the dip. The differences are insignificant, except when the inclination is very high; the greater part of the declinations observed in the high dips were antecedent to the 1st of March 1842, when the ship commenced her return to the lower latitudes; for these the table computed with $a = \cdot 0267$ has been employed, and appears to answer better than the corrections computed either by the values resulting from the observations at Hobarton before the commencement, or by those at the Falkland Islands after the conclusion of the voyage.

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* Philosophical Transactions, 1843, Part II. pp. 152–154.

† Ibid. pp. 152, 153.

2. *In the Terror.*—For the values of a and b in the Terror, we have observations on each of the thirty-two principal points of the compass at Hobarton in October 1840, and a second series in June 1841, as follows:—

Ship's head by compass.	Disturbance towards the west.			Ship's head by compass.	Disturbance towards the west.		
	1840.	1841.	Mean.		1810.	1841.	Mean.
N.	+0° 42′·4	−0° 52′	−0° 05′	S.	−0° 11′·6	−0° 55′	−0° 33′
N. by W.	−0 23·6	−0 52	−0 38	S. by E.	+0 52·4	−0 06	+0 23
N.N.W.	−1 20·6	−0 59	−1 10	S.S.E.	+1 56·4	+0 43	+1 20
N.W. by N.	−2 20·6	−0 03	−1 12	S.E. by S.	+2 38·4	+2 08	+2 23
N.W.	−3 25·6	−0 58	−2 12	S.E.	+3 19·4	+2 57	+3 08
N.W. by W.	−3 56·6	−2 12	−3 04	S.E. by E.	+4 00·4	+3 48	+3 54
W.N.W.	−4 01·6	−2 26	−3 14	E.S.E.	+4 43·4	+5 25	+4 54
W. by N.	−4 06·6	−2 51	−3 29	E. by S.	+4 28·4	+4 58	+4 43
W.	−4 36·6	−3 34	−4 06	E.	+4 24·4	+4 27	+4 26
W. by S.	−4 44·6	−3 43	−4 14	E. by N.	+4 11·4	+4 02	+4 07
W.S.W.	−4 52·6	−4 34	−4 43	E.N.E.	+4 07·4	+3 27	+3 47
S.W. by W.	−5 22·6	−4 01	−4 42	N.E. by E.	+3 27·4	+3 04	+3 16
S.W.	−4 23·6	−3 50	−4 07	N.E.	+3 02·4	+3 01	+3 02
S.W. by S.	−3 31·6	−4 22	−3 57	N.E. by N.	+2 37·4	+2 27	+2 32
S.S.W.	−2 03·6	−3 41	−2 52	N.N.E.	+2 11·4	+0 46	+1 29
S. by W.	−1 37·6	−2 44	−1 11	N. by E.	+1 26·4	−0 12	+0 37

We have also a series at Port Louis, in the Falkland Islands, in August 1842, as follows:—

Ship's head by compass.	Disturbance towards the west.	Ship's head by compass.	Disturbance towards the west.	Ship's head by compass.	Disturbance towards the west.	Ship's head by compass.	Disturbance towards the west.
N.	+0° 19′	W.	−2° 30′	S.	−0° 16′	E.	+2° 46′
N. by W.	−0 02	W. by S.	−2 21	S. by E.	−0 08	E. by N.	+2 27
N.N.W.	−0 17	W.S.W.	−2 12	S.S.E.	0 00	E.N.E.	+1 58
N.W. by N.	−0 48	S.W. by W.	−2 21	S.E. by E.	+0 47	N.E. by E.	+1 39
N.W.	−1 19	S.W.	−1 33	S.E.	+1 35	N.E.	+1 13
N.W. by W.	−1 49	S.W. by S.	−1 05	S.E. by E.	+2 17	N.E. by N.	+1 11
W.N.W.	−1 47	S.S.W.	−0 47	E.S.E.	+3 04	N.N.E.	+0 34
W. by N.	−2 07	S. by W.	−0 45	E. by S.	+2 33	N. by E.	+0 27

From these observations we have the following values of the constants:—

Hobarton . . . . $a=+{\cdot}0275$; $b=+{\cdot}979$
Falkland Islands . . . $a=+{\cdot}0293$; $b=+{\cdot}994$.

These values are nearly the same as those derived from the observations in the Erebus at the same periods, and appear to require no special remark; the same tables have been employed in the declination corrections of both ships during the voyage under notice; the values of the constants in these tables were as follows:—

$a={\cdot}0267$ when the ships were sailing from the lower into the higher latitudes; $a={\cdot}0288$ when sailing from the higher into the lower latitudes; $b=+{\cdot}984$ in both cases.

Deduction of the Corrections on account of the Ship's attraction for the Observations of Inclination.

1. *In the Erebus.*—The spot in the ship in which Mr. Fox's apparatus for the observations of inclination and intensity was employed, was a few feet in advance (towards the bow), and about two feet lower in height, than the position of the standard compass.

The values of a and b derived from the observations with the compass needle apply in strictness only to the spot in which that compass was stationed; it may be proper, therefore, before we employ them for the observations with Mr. Fox's apparatus, to show that nearly similar values for the constant a in particular (the more important constant) are deducible from the observations of inclination and intensity, independently of those made with the compass needle. For this purpose we may employ equation (1.), Phil. Trans., 1843, Part II. p. 147, viz.

$$\frac{\varphi'}{A'\varphi}\cos\theta'\cos\zeta'=\cos\theta\cos\zeta+a\sin\theta,$$

obtaining by its means the value of a from the observations of inclination and intensity made at Hobarton and Port Louis. As A′ is known to differ very slightly, if at all, from unity, we have from equation (1.),

$$a\sin\theta=\frac{\varphi'}{\varphi}\cos\theta'\cos\zeta'-\cos\theta\cos\zeta.$$

φ and θ are furnished by the mean of the observations of inclination and intensity on the sixteen points of the compass, having approximate corrections applied to each of them; φ' and θ' by the (uncorrected) observations on the different points.

From the general aspect of the observations at both stations, we may conclude that the same symmetrical distribution of the iron existed in reference to the position of Mr. Fox's apparatus as in the case of the standard compass, and consequently that at the north and south points the value of ζ' and ζ coincided, being equal in the one case to 0°, and in the other to 180°. At Hobarton (in June 1841) we have $\varphi=1{\cdot}83$, $\theta=-70°\,39'$; φ' at north 1·812, at south 1·854; θ' at north $-71°\,56'$, at south $-69°\,14'$:

Hence

$$\left.\begin{array}{l}\text{at north,} -{\cdot}944a=+{\cdot}307-{\cdot}331\\ \text{at south,} -{\cdot}944a=-{\cdot}359+{\cdot}331\end{array}\right\}\text{; whence } a=+{\cdot}0275.$$

At Port Louis (August 1842) we have $\varphi=1{\cdot}32$; $\theta=-52^\circ\ 05'$; φ' at north $=1{\cdot}279$, at south $=1{\cdot}346$; θ' at north $=-52^\circ\ 50'$, at south $=-51^\circ\ 33$; hence

$$\left.\begin{array}{l}\text{at north,} -{\cdot}789a=+{\cdot}5920-{\cdot}615\\ \text{at south,} -{\cdot}788a=-{\cdot}6367+{\cdot}615\end{array}\right\}\text{; whence } a=+{\cdot}0310.$$

The accordance between these values and those deduced from the observations with the standard compass is fully sufficient to justify the inference that the effect of the ship's attraction was very nearly the same at the spot where Mr. Fox's apparatus was used, as at that at which the standard compass was fixed.

We may obtain c either by equation (11.), Phil. Trans., 1843, Part II. p. 148,

$$c\cos\zeta+d\tan\theta=\sqrt{(\cos\zeta+a\tan\theta)^2+b^2\sin^2\zeta}.\tan\theta';$$

or from the observations of inclination and intensity, independently of the values of a and b, by the equation

$$\frac{\varphi'}{\varphi}\sin\theta'=c\cos\theta\cos\zeta-d\sin\theta.$$

Confining ourselves to the north and south points, and to those points on either side of N. and S. from which c may be most advantageously derived, the observations at Hobarton give the following values to be employed in the equations:

$$\text{N.}; \ \zeta'=0; \quad \zeta=0; \quad \theta'=-71^\circ\ 56'; \ \varphi'=1{\cdot}812.$$

$$\left.\begin{array}{l}\text{N.N.E.}\\ \text{N.N.W.}\end{array}\right\}; \ \zeta'=22^\circ\ 30'; \ \zeta=21^\circ\ 03'; \ \theta'=-71^\circ\ 55'; \ \varphi'=1{\cdot}812.$$

$$\left.\begin{array}{l}\text{N.E.}\\ \text{N.W.}\end{array}\right\}; \ \zeta'=45^\circ\ 0'; \ \zeta=42^\circ\ 12'; \ \theta'=-71^\circ\ 48'; \ \varphi'=1{\cdot}816.$$

$$\left.\begin{array}{l}\text{S.E.}\\ \text{S.W.}\end{array}\right\}; \ \zeta'=135^\circ\ 0'; \ \zeta=131^\circ\ 17'; \ \theta'=-69^\circ\ 56'; \ \varphi'=1{\cdot}847.$$

$$\left.\begin{array}{l}\text{S.S.E.}\\ \text{S.S.W.}\end{array}\right\}; \ \zeta'=157^\circ\ 30'; \ \zeta=155^\circ\ 24'; \ \theta'=-69^\circ\ 38'; \ \varphi'=1{\cdot}850.$$

$$\text{S}; \ \zeta'=180^\circ\ 0'; \ \zeta=180^\circ\ 0'; \ \theta'-69^\circ\ 14'; \quad \varphi'=1{\cdot}854.$$

$$\theta=-70^\circ\ 39'; \ \varphi=1{\cdot}83.$$

Substituting these values in the first of the above equations (11.), we have at

$$\text{N.} \qquad 1{\cdot}000c-2{\cdot}85d=-2{\cdot}828;$$

$$\left.\begin{array}{l}\text{N.N.E.}\\ \text{N.W.}\end{array}\right\} \quad {\cdot}934c-2{\cdot}85d=-2{\cdot}832;$$

$$\left.\begin{array}{l}\text{N.E.}\\ \text{N.W.}\end{array}\right\} \quad {\cdot}741c-2{\cdot}85d=-2{\cdot}841;$$

$$\left.\begin{array}{l}\text{S.E.}\\ \text{S.W.}\end{array}\right\}- \ {\cdot}660c-2{\cdot}85d=-2{\cdot}853;$$

$$\left.\begin{array}{l}\text{S.S.E.}\\ \text{S.S.W.}\end{array}\right\}-\cdot909c-2\cdot85d=-2\cdot876\,;$$

$$\text{S.}\quad -1\cdot000c-2\cdot85d=-2\cdot843.$$

Changing the signs of the three last equations, and summing, we have

$$5\cdot24c=+\cdot071\,;$$

whence $c=+\cdot014.$

To obtain c from the observations of inclination and intensity alone, we have at

$$\text{N.}\quad \cdot331c-\cdot94d=-\cdot941\,;$$

$$\left.\begin{array}{l}\text{N.N.E.}\\ \text{N.N.W.}\end{array}\right\}\ \cdot309c-\cdot94d=-\cdot942\,;$$

$$\left.\begin{array}{l}\text{N.E.}\\ \text{N.W.}\end{array}\right\}\ \cdot222c-\cdot94d=-\cdot943\,;$$

$$\left.\begin{array}{l}\text{S.E.}\\ \text{S.W.}\end{array}\right\}-\cdot218c-\cdot94d=-\cdot948\,;$$

$$\left.\begin{array}{l}\text{S.S.E.}\\ \text{S.S.W.}\end{array}\right\}-\cdot301c-\cdot94d=-\cdot948\,;$$

$$\text{S.}\quad -\cdot331c-\cdot94d=-\cdot947.$$

Changing the signs of the three last equations, and summing, d is eliminated as before, and

$$c=\frac{+\cdot017}{1\cdot71}=+\cdot010.$$

From the observations at Port Louis, we have the following values to be employed in the equations:

$$\text{N.}\quad \zeta'=0\,;\qquad \zeta=0\,;\qquad \theta'=-52^\circ\,50'\,;\ \varphi'=1\cdot279\,;$$

$$\left.\begin{array}{l}\text{N.N.E.}\\ \text{N.N.W.}\end{array}\right\}\zeta'=\ 22^\circ\,30'\,;\ \zeta=\ 22^\circ\,01'\,;\ \theta'=-52^\circ\,42'\,;\ \varphi'=1\cdot290\,;$$

$$\left.\begin{array}{l}\text{N.E.}\\ \text{N.W.}\end{array}\right\}\zeta'=\ 45^\circ\ \ 0'\,;\ \zeta=\ 43^\circ\,58'\,;\ \theta'=-52^\circ\,45'\,;\ \varphi'=1\cdot290\,;$$

$$\left.\begin{array}{l}\text{S.E.}\\ \text{S.W.}\end{array}\right\}\zeta'=135^\circ\ \ 0'\,;\ \zeta=133^\circ\,03'\,;\ \theta'=-51^\circ\,59'\,;\ \varphi'=1\cdot323.$$

$$\left.\begin{array}{l}\text{S.S.E.}\\ \text{S.S.W.}\end{array}\right\}\zeta'=157^\circ\,30'\,;\ \zeta=155^\circ\,52'\,;\ \theta'=-51^\circ\,33'\,;\ \varphi'=1\cdot330.$$

$$\text{S.}\quad \zeta'=0\,;\qquad \zeta=0\,;\qquad \theta'=-51^\circ\,43'\,;\ \varphi'=1\cdot346.$$

$$\theta=-52^\circ\,05'\,;\ \varphi=1\cdot32.$$

Substituting these values in equation (11.), we obtain

$$c=\frac{+\cdot094}{5\cdot24}=+\cdot018\,;$$

or from the observations of inclination and intensity alone,

$$c=\frac{+\cdot051}{3\cdot22}=+\cdot016.$$

The correspondence in the value of the constants obtained from the observations at Hobarton and Port Louis, being the commencing and concluding stations of the voyage now under consideration, is fully as good as could be desired; and a table formed from them has been employed for the correction of the observations made between Hobarton and the Bay of Islands, and during the return of the Expedition from the high latitudes to the Falkland Islands commencing with the 1st of March 1842. In those portions of the voyage the ship was passing from the higher to the lower magnetic latitudes, in which circumstance they corresponded with the observations at Hobarton and Port Louis, which were both made on the return from the vicinity of the magnetic pole. But if we attempt to apply the same table to the observations made under the reverse circumstances, namely, when the ship was passing from the lower to the higher latitudes (and such was the case with the greater part of the observations which we have to correct in the present voyage), we find that the tabular numbers, where the N. and S. points are approached, furnish a decided over compensation. On days when observations have been made at or near the N. and S. points, if we seek in the table for the corrections which should bring the results in accord with each other, we find that the corrections which will do so belong to a dip which is always some degrees less than the true terrestrial dip. It appeared desirable, therefore, if possible, to form a table for the correction of the observations of this portion of the voyage, derived from those observations themselves. Fortunately we have a better opportunity of doing this than might have been anticipated. The progress of the Expedition was so much impeded by ice in the early part of January 1842, that from the 6th to the 16th inclusive, the Erebus was the whole time between the latitudes of $-65° 54'$ and $-66° 14'$, and between the longitudes of $204° 33'$ and $202° 02'$; the weather and all other circumstances being favourable, the inclination was observed in the course of those eleven days with the ship's head on seventeen different points of the compass, sufficiently distributed, and particularly towards the north points and south points, where the effect of the ship's attraction is greatest, and is in opposite directions. From the observations at north and south it is not difficult to obtain an approximate value of a, which should bring the corrected results at those points into accord. The value thus obtained is about $+\cdot023$. I have collected the observations during the period referred to into the following table, taking, for the sake of simplicity, only those observations which were made by the *direct* method, which, however, comprises by far the greater part of the observations of that period. I have then computed the corrections, first, with the values of the constants, such as they are given by the observations made for their determination at Hobarton and the Falkland Islands (being the commencement and close of the voyage), viz. $a=+\cdot028$; $b=+\cdot984$; $c=+\cdot015$ and $d=1$; and second, with $a=+\cdot023$, b, c and d, as before; and have placed the two series of corrected results in the table, with columns showing in both cases the difference of the corrected result, on each point, from the mean result. A comparison of those columns seems conclusive in favour of the application of the smaller value of a to those observations which were made when the ship was in progress from the lower to the higher latitudes. If a be taken as it was found at Hobarton and the Falkland Islands, not only are the differences generally greater, but they are systematically so; evidencing an over compensation where the north and south points are approached; whilst with the smaller value of a the differences are greatly diminished in amount, and exhibit no appearance whatsoever of system. They are such as may well be supposed to have been occasioned partly by observation error, and partly by small differences of geographical position in which the observations themselves were made.

Ship's head by compass.	Number of observations.	Inclination observed.	Values of the Constants. $a=+\cdot028$. $b=+\cdot984$; $c=+\cdot015$; $d=1$.			Values of the Constants. $a=+\cdot023$. $b=+\cdot984$; $c=+\cdot015$; $d=1$.		
			Computed corrections.	Inclinations corrected.	$\alpha-\beta$.	Computed corrections.	Inclinations corrected.	$\alpha-\beta$.
				β.			β.	
		° ′	° ′	° ′	′	° ′	° ′	′
N.	1	−80 58	+1 32	−79 26	−20	+1 16	−79 42	− 3
N.N.E.	2	−81 00	+1 27	−79 33	−13	+1 12	−79 48	+ 3
N.E.	2	−80 42	+1 12	−79 30	−26	+1 00	−79 42	− 3
N.W.	3	−80 35	+1 12	−79 23	−23	+1 00	−79 35	−10
N.E. by E.	2	−80 50	+1 01	−79 49	+ 3	+0 55	−79 55	+10
W.	1	−79 58	+0 17	−79 41	− 5	+0 14	−79 44	− 1
E.	3	−79 50	+0 17	−79 33	−13	+0 14	−79 36	− 9
E. by S.	1	−79 45	−0 01	−79 46	−00	−0 01	−79 46	+ 1
S.W. by W.	3	−79 19	−0 38	−79 57	+11	−0 31	−79 50	+ 5
S.W. ¾ W.	1	−79 30	−0 42	−80 12	+26	−0 34	−80 04	+19
S.W. ½ W.	1	−79 10	−0 46	−79 56	+10	−0 38	−79 48	+ 3
S.E.	1	−79 08	−0 55	−80 03	+17	−0 45	−79 53	+ 8
S.W.	3	−78 52	−0 55	−79 47	+ 1	−0 45	−79 37	− 8
S.W. ½ S.	1	−78 48	−1 02	−79 50	+ 4	−0 50	−79 38	− 7
S.S.E.	3	−78 28	−1 13	−79 41	− 5	−1 05	−79 33	−12
S. by W.	3	−78 28	−1 29	−79 57	+11	−1 13	−79 41	− 2
S.	5	−78 32	−1 31	−80 03	+17	−1 14	−79 46	+ 1
Means	36	....	....	−79 46 $=\alpha$		....	−79 45 $=\alpha$	

The mean of the observations in the table thus corrected is −79° 45′; the corresponding geographical position is −66° 04′, and 203° 17′·5, if we take as such the middle point of the geographical space in which the ship was detained from the 6th to the 16th of January. The inclination observed on the ice on the 16th of January, in lat. −65° 49′, long. 202° 02′, with needles whose poles were reversed, was −79° 39′·5. We can derive no *precise* conclusion in regard to the value of d, from observations which are not identical in locality; but the accordance of the results obtained on board and on the ice, in geographical positions so little different, is quite sufficient to show that the error involved by assuming d as unity must be, at the utmost, very inconsiderable.

The tables for the correction of the inclination in the Erebus have therefore been computed with the following values for the constants, viz. from New Zealand to the end of February 1842, being the portion of the voyage in which the ship was in progress from the lower into the higher inclinations, $a=+\cdot023$, $b=+\cdot984$, $c=+\cdot015$ and $d=1$: and for the remainder of the voyage $a=+\cdot028$, b, c and d, as before.

In the Terror.—The place in which Mr. Fox's apparatus was used in the Terror was about the same distance from the position of the standard compass, and in the same direction, as in the Erebus. A series of observations were made with it for the purpose of furnishing materials for the determination of the constants, at Hobarton in June 1841, and at the Falkland Islands in August 1842; and the inclination was also observed with the ship's head on several points of the compass during the detention of the ships by the ice between the 6th and 16th of January 1842. In the case of the Erebus, we have found these latter observations of principal use in furnishing the values of the constants which apply to the greater part of the observations of the voyage; it may, therefore, be advisable to commence with the discussion of the corresponding series in the Terror.

Inclinations observed on board Her Majesty's ship Terror with needle F.C.B. used direct, during her detention by the ice from the 6th to the 16th of January 1842, between the latitudes of −65° 45′ and −66° 20′, and longitudes of 201° 46′ and 204° 04′.

Ship's head by compass.	Number of observations.	Inclination observed.	Ship's head by compass.	Number of observations.	Inclination observed.
		° ′			° ′
N.	4	−81 19·5	S.	6	−78 30
N. ½ E.	2	−81 14	S. ¾ W.	1	−78 21
N. ¾ E.	1	−80 50	S. by W.	1	−78 48
N.N.E.	3	−80 57	S.W. by W. ½ W.	1	−78 50
N.E.	2	−80 48	S.W. by S.	3	−79 00
N.E. by E.	1	−80 26	S.W.	3	−79 08
E. ½ N.	1	−79 57	S.W. ½ W.	1	−79 08
E.	6	−79 55	S.W. by W.	5	−79 21
E. ½ S.	1	−79 45	W.S.W.	2	−79 37
E. by S.	1	−79 33	W. by S.	1	−80 05
E.S.E.	2	−79 21	W. ¼ S.	2	−80 07
S.E. by E. ½ E.	1	−79 04	N.W.	2	−81 09
S.S.E.	1	−78 42	N. by W.	1	−81 15
S. by E.	4	−78 37			

These observations manifest the general systematic character of the disturbance occasioned by the ship's attraction; they furnish indeed a remarkable example of the success with which the effect of the ship's iron on the inclination may be investigated by observations made at sea. The disturbance appears to have not been strictly symmetrical, inasmuch as the inclinations observed on the western points somewhat exceed in amount those observed on the corresponding eastern points; the same circumstance took place in the observations at Hobarton; but at the Falkland Islands, on the contrary, the inclinations observed on the eastern points were generally somewhat the higher. A similar occasional departure from strict symmetry has before been noticed in the effect of the ship's iron on the compass needle*; in that case also the disturbance in the same ship was sometimes greater on the eastern, and sometimes on the western points; these small irregularities, having no uniform character, are regarded as included amongst those varying accidents which are classed generally under the name of observation error. It is proper, however, in consequence of this occasional irregularity, that the data from which constants are to be derived for general corrections should consist of the mean of observations on corresponding points on the east and west sides of the compass; in this view we have as available observations in the preceding table those on the following points of the compass.

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* Philosophical Transactions, 1843, Part II. p. 152.

	°	′
North	−81	19·5
N.W.	−80	58·5
N.E.		
W. ¼ S.	−79	58·5
E. ¼ S. (from E. and E. ½ S.)		
W. by S.	−79	49
E. by S.		
W.S.W.	−79	29
E.S.E.		
S.W.	−79	04·5
S.E. (from E.S.E. and S.S.E.)		
South	−78	30

We have here 2° 49′·5 for the difference between the inclinations observed with the ship's head north and south; the value of *a* which will give that amount for the sum of the corrections at north and south when the dip is between −79° and −80°, (neglecting *c* as too small in such case to require consideration), is about +·026. The observations at north were four in number,—those at south six, and on different days,—they were as follows:—

North.			South.		
	°	′		°	′
January 8,	−81	19	January 7,	−78	28
8,	−81	20	8,	−78	31
8,	−81	18	11,	−78	28
13,	−81	21	13,	−78	25
			13,	−78	33
Mean	81	19·5	14,	−78	34
			Mean	78	30

From the accord which these observations respectively exhibit, it is clear that we should not be justified in taking a value of *a* which should differ much from +·026.

If we now refer to the observations which were made in the Terror soon after her arrival at the Falkland Islands, when the ship's head was placed on the principal points of the compass for the purpose of determining the values of the constants, we shall find that a value of a taken near +·026 will by no means bring the results on the N. and S. points, or on those approaching the N. and S. points, into accord; and that as we have already found in the dip corrections of the Erebus, and in the declination corrections of both ships, a considerably higher value of a is required for the observations on the return from the high latitudes, than for those when the ship was in progress from the lower to the higher dips.

We have no observations at the Falkland Islands (made at the spot in the ship where Mr. Fox's apparatus was used) either of the direction of the compass needle, or of the force acting on the horizontal needle: we must therefore obtain a and b directly from the observations of Inclination and Intensity. The observations gave as follows:—

Ship's head.	Inclination observed. $\theta = -51^\circ\ 56'$.		Intensity observed. $\varphi = 1·336$.	
	θ'		φ'	
N.	−52° 46′·5	−52° 46′·5	1·320	1·320
N.N.E.	−52 51	−52 47	1·315	1·314
N.N.W.	−52 43		1·313	
N.E.	−52 47	−52 46	1·314	1·313
N.W.	−52 45		1·312	
E.N.E.	−52 52	−52 45	1·336	1·322
W.N.W.	−52 38		1·308	
E.	−52 31	−52 22	1·336	1·330
W.	−52 13		1·324	
E.S.E.	−52 16	−52 01	1·355	1·350
W.S.W.	−51 46		1·345	
S.E.	−51 32	−51 32	1·370	1·364
S.W.	−51 32		1·359	
S.S.E.	−51 09	−51 15	1·368	1·367
S.S.W.	−51 21		1·366	
S.	−50 53	−50 53	1·370	1·370

For a, we have from equation (1.),

$$a\sin\theta = \frac{\varphi'}{\varphi}\cos\theta'\cos\zeta' - \cos\theta\cos\zeta,$$

whence we obtain, from the observations on the N. and S. points, $a = +·0311$, and from those on the N.N.E. and N.N.W., S.S.E. and S.S.W. points, a also $= +·0311$.

In the Erebus we have found a for the spot in the ship where Mr. Fox's apparatus was used $= +·023$, from the observations made when the ship was in progress to the southward; and $= +·029$ at Hobarton and the Falkland Islands. The corresponding values in the Terror are +·026 and +·031.

In the case of the Terror, therefore, I have employed separate tables for the corrections for the ship's attraction, viz. a taken as +·028 in the passage from Hobarton to New Zealand; as +·026 in the passage to the higher latitudes; and as +·031 during the return from the high latitudes to the Falkland Islands.

For b and c, we obtain from the observations at the Falkland Islands as follows:—

In the case of b, we have from equation (2.),

$$b\cos\theta = \frac{\varphi'}{\varphi}\cos\theta'\sin\zeta'\operatorname{cosec}\zeta;$$

the observations at N.E., N.W., S.E. and S.W. give $b=+{\cdot}984$; those at E.N.E., W.N.W., E.S.E. and W.S.W., $b={\cdot}984$; and those at E. and W. $b={\cdot}982$.

In the case of c, we have from equation (3.),

$$\frac{\varphi'}{\varphi}\sin\theta' = c\cos\theta\cos\zeta + d\sin\theta;$$

from the observations at N. to N.E. and N.W. inclusive, and from S. to S.E. and S.W. inclusive, eliminating d, we have

$$c=+{\cdot}009.$$

The constant d is perhaps the most difficult of the constants to ascertain satisfactorily, as its value derivable from the observations depends on a knowledge of the true geographical dip at the place of observation, free from what is now known as *station error*. Experience has fully shown the general fact, that inclinations observed on land cannot safely be assumed as free from local disturbance. The discrepancies of gravitation at the Falkland Islands are well known from the experiments with the pendulum; and from the geological character of these islands, we might be prepared to expect the existence of magnetic discrepancies also. By the needles in both ships, the inclination was found a third of a degree higher at the magnetic observatory on shore than when observed on board in the harbour; if the observatory dip were to be assumed as an undisturbed one, we should obtain d in both ships considerably less than unity, whereas from the comparison of the observations in both ships in the preceding December and January, with the inclination observed at the same time on the ice over a deep sea, where no local attraction can be imagined to exist, we have d (as far as the small differences of geographical position will permit us to judge) differing scarcely, if at all, from unity in either ship. The preference is certainly due to the deduction from the results obtained on the ice. Taking therefore $d=1$, $c=+{\cdot}01$, $b={\cdot}984$ and $a=+{\cdot}026$, we have the corrections, and the corrected inclination, of the observations in the Terror between the 6th and 16th of January as follows:

Ship's head.	No. of observations.	Inclination observed.	Correction.	Corrected Inclination.	
N.	4	−81° 19′·5	+1° 26′	−79° 53′·5	−79° 52′·4
N.W. N.E.	4	−80 58·5	+1 09	−79 49·5	
W. ¼ S. E. ¼ S.	9	−79 58·5	+0 12	−79 46·5	
W. by S. E. by S.		−79 49·0	−0 01	−79 50·0	
W.S.W. E.S.E.	4	−79 29·0	−0 17·5	−79 56·5	
S.W. S.E.	6	−79 04·5	−0 51·5	−79 56·0	
S.	6	−78 30·0	−1 24·5	−79 54·5	

Slight differences in the corrected results must be looked for, as the observations were not all taken precisely at the same geographical spot: those which appear in the table are, however, very slight; the accord produced by the corrections seems as satisfactory as could be wished or expected; and I have accordingly taken the above stated values of *b*, *c*, and *d*, for the whole period under notice.

On a general review of the examination to which the observations in the Erebus and Terror in this and the preceding voyage have been subjected, in reference to the magnetic influence of their iron, we find reason to conclude from the consistent experience of both voyages, that the disturbance in them was altogether such as would be occasioned by the magnetism induced in the soft iron of the ship by the magnetism of the earth,—if we permit ourselves to include as possessing the quality of softness, certain portions of iron which, though not permanently magnetic, do still retain polarity, and require some time to conform to the changes in magnetical relations induced by changes of geographical position. It is not improbable that this may be a general case in sailing vessels similar to the Erebus and Terror; but we should by no means be warranted in deriving a corresponding inference in regard to ships which contain steam machinery, and still less in the case of iron vessels. These may possibly possess permanent magnetism strictly so called; in addition to induced magnetism, and temporarily-abiding polarity. It is very desirable that we should have some means of judging of what may be expected in vessels of these two classes. The knowledge would be valuable were it only for the compass corrections necessary for the ordinary purposes of navigation; and it appears indispensable before a correct judgment can be formed of the confidence to which methods may be entitled, which have been already, or may hereafter be devised, to supersede these corrections by the employment of compensating forces. It is not necessary that steam or iron-built ships should perform voyages like those of the Erebus and Terror to procure this knowledge; a voyage from the British Channel to the Tropics would be sufficient; the ship should be swung before her departure from these islands, and immediately on her arrival in the Tropics, and at intervals of three or six months during her continuance there; the experiment should also be repeated on her return to England before any material alteration is made in the distribution of her iron.

Index Correction.

Index Correction of R. F. 5 *for the Observations of the Inclination in the Erebus.*—The observations at sea with this needle having been made in the one position of the instrument only, viz. with the face of the circle towards the east, and the marked side of the needle towards the observer,—we have to obtain the index correction, by comparing the inclinations observed in the same manner on shore, or on the ice, with the results given at the same places by needles of which the poles were reversed and the needle and circle used in the eight ordinary positions.

The stations which furnish this comparison are Hobarton, Sydney, New Zealand, the Falkland Islands, and two stations on the ice in the latitudes of $-63° 23'$ and $-65° 49'$. The results of the observations at Hobarton with needles with which the complete process for determining the inclination was gone through, were given in No. V. of these Contributions[*]. Those at the other five stations are as follows:—

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[*] Philosophical Transactions, 1843, Part II. p. 165.

Observations of the Inclination, with Needles whose Poles were reversed, made at Garden Island, Sydney, July 1841.

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1841.	h m		° ′	° ′	
July 20.	9 20 A.M.	R 4	α −62 52·5	−62 49·5	Needles belonging to H.M.S. Erebus.
			β −62 46·5		
20.	10 45 A.M.	R 10	α −62 57·5	−62 45·6	
			β −62 33·7		
20.	1 00 P.M.	R 6	α −62 50·1	−62 54·3	
			β −62 58·5		
20.	2 15 P.M.	R 7	α −62 53·9	−62 52·9	
			β −62 51·9		
20.	9 00 A.M.	C 1	α −62 48·2	−62 46·9	Needles belonging to H.M.S. Terror.
			β −62 45·6		
		C 2	α −62 49·6	−62 45·1	
			β −62 40·5		
				−62 49·1	General Mean.

Observations of the Inclination, with Needles whose Poles were reversed, made at the Bay of Islands, New Zealand, August to November 1841.

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1841.	h m		° ′	° ′	
August 23.	2 10 P.M.	R 10	α −59 46·1	−59 31·5	Needles belonging to H.M.S. Erebus.
			β −59 16·9		
23.	3 10 P.M.	R 4	α −59 38·5	−59 33·0	
			β −59 27·5		
24.	8 40 A.M.	R 4	α −59 38·4	−59 32·1	
			β −59 25·8		
24.	9 45 A.M.	R 10	α −59 53·9	−59 37·4	
			β −59 21·3		
24.	11 00 A.M.	R 6	α −59 28·8	−59 31·4	
			β −59 34·0		
24.	1 10 P.M.	R 7	α −59 30·3	−59 30·4	
			β −59 30·6		
October 5.	4 00 P.M.	R 4	α −59 39·7	−59 33·5	
			β −59 27·3		
12.	7 00 A.M.	R 4	α −59 35·2	−59 31·8	
			β −59 27·9		
26.	6 35 A.M.	R 4	α −59 35·7	−59 31·9	
			β −59 28·1		
26.	9 35 A.M.	R 10	α −59 50·5	−59 38·5	
			β −59 26·6		
26.	10 35 A.M.	R 6	α −59 30·1	−59 30·8	
			β −59 31·4		
26.	1 30 P.M.	R 7	α −59 32·4	−59 34·3	
			β −59 36·2		
August 23.	9 00 A.M.	C 1	α −59 30·0	−59 28·9	Needles belonging to H.M.S. Terror.
			β −59 27·8		
23.	11 30 A.M.	C 2	α −59 31·4	−59 27·0	
			β −59 22·7		
November 6.	9 00 A.M.	C 1	α −59 32·5	−59 30·3	
			β −59 28·1		
6.	10 30 A.M.	C 2	α −59 32·8	−59 26·8	
			β −59 20·8		
				−59 31·9	General Mean.

Observations of the Inclination with Needles whose Poles were reversed, made on the ice.

Date.	Lat.	Long.	Needle.	Poles. α direct. β reversed.	Mean.		Remarks.
1841. December 19.	−63° 23′	210° 02′	R 4	α−77° 23′·1 β−77 23·4	−77° 23′·3	−77° 23′·3	Needles belonging to H.M.S. Erebus.
23.	−65 59	204 14	R 4	α−79 32·0 β−79 24·7	−79 28·4	−79 31·0	
23.	−65 59	204 14	R 6	α−79 35·6 β−79 31·5	−79 33·6		
1842. January 16.	−65 49	202 02	R 4	α−79 40·5 β−79 34·4	−79 37·4	−79 39·5	
16.	−65 49	202 02	R 6	α−79 36·2 β−79 42·9	−79 39·6		
16.	−65 49	202 02	R 7	α−79 41·8 β−79 41·0	−79 41·4		

Observations of the Inclination, with Needles whose Poles were reversed, made at the Magnetic Observatory at Port Louis, in the Falkland Islands, April to August 1842.

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1842. April 12.	h m 1 30 P.M.	R 4	α −52° 33′·5 β −52 16·7	−52° 25′·1	Needles belonging to H.M.S. Erebus.
12.	3 30 P.M.	R 6	α −52 26·0 β −52 32·0	−52 29·0	
12.	3 30 P.M.	R 7	α −52 30·8 β −52 30·9	−52 30·8	
15.	8 20 A.M.	R 4	α −52 36·8 β −52 16·3	−52 26·6	
15.	3 10 P.M.	R 4	α −52 39·9 β −52 12·4	−52 26·2	
19.	8 00 A.M.	R 4	α −52 36·9 β −52 17·8	−52 27·3	
19.	3 30 P.M.	R 4	α −52 35·8 β −52 16·2	−52 26·3	
22.	8 00 A.M.	R 4	α −52 36·3 β −52 16·8	−52 26·5	
22.	3 30 P.M.	R 4	α −52 36·8 β −52 15·3	−52 26·1	
26.	8 00 A.M.	R 4	α −52 35·9 β −52 10·3	−52 23·1	
26.	3 30 P.M.	R 4	α −52 36·0 β −52 08·7	−52 22·3	
29.	8 00 A.M.	R 4	α −52 38·3 β −52 18·8	−52 28·6	
May 3.	8 00 A.M.	R 4	α −52 35·8 β −52 06·4	−52 21·1	
3.	3 30 P.M.	R 4	α −52 36·8 β −52 16·9	−52 26·8	
6.	8 00 A.M.	R 4	α −52 36·3 β −52 17·1	−52 26·7	
6.	3 30 P.M.	R 4	α −52 37·3 β −52 14·9	−52 26·1	

Observations of Inclination. (Continued.)

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1842.	h m		° ′	° ′	
May 10.	10 30 A.M.	R 4	α −52 31·2 β −52 25·2	−52 28·2	Needles belonging to H.M.S. Erebus.
10.	3 00 P.M.	R 4	α −52 24·3 β −52 30·6	−52 27·5	
13.	8 00 A.M.	R 4	α −52 36·7 β −52 14·5	−52 25·6	
13.	3 30 P.M.	R 4	α −52 37·0 β −52 13·5	−52 25·3	
17.	8 00 A.M.	R 4	α −52 35·6 β −52 15·3	−52 25·5	
17.	3 30 P.M.	R 4	α −52 33·4 β −52 17·7	−52 25·5	
20.	8 00 A.M.	R 4	α −52 36·8 β −52 13·2	−52 25·0	
20.	3 30 P.M.	R 4	α −52 34·3 β −52 13·0	−52 23·7	
24.	8 00 A.M.	R 4	α −52 36·5 β −52 18·6	−52 27·7	
24.	3 30 P.M.	R 4	α −52 37·6 β −52 17·7	−52 27·7	
27.	8 00 A.M.	R 4	α −52 23·5 β −52 12·5	−52 23·0	
27.	3 30 P.M.	R 4	α −52 32·8 β −52 14·0	−52 23·4	
June 1.	8 00 A.M.	R 4	α −52 37·1 β −52 16·0	−52 26·5	
1.	3 30 P.M.	R 4	α −52 35·3 β −52 16·2	−52 25·7	
4.	8 00 A.M.	R 4	α −52 35·4 β −52 17·7	−52 26·5	
4.	3 30 P.M.	R 4	α −52 36·3 β −52 16·9	−52 26·6	
7.	8 00 A.M.	R 4	α −52 36·4 β −52 15·4	−52 25·9	
7.	8 00 A.M.	R 4	α −52 29·0 β −52 13·7	−52 26·4	
10.	8 00 A.M.	R 4	α −52 38·4 β −52 16·4	−52 27·4	
10.	3 30 P.M.	R 4	α −52 35·9 β −52 17·6	−52 26·8	
14.	8 00 A.M.	R 4	α −52 35·8 β −52 16·2	−52 26·0	
14.	3 30 P.M.	R 4	α −52 41·3 β −52 13·2	−52 27·3	
17.	8 00 A.M.	R 4	α −52 34·8 β −52 14·7	−52 24·8	
17.	10 00 A.M.	R 6	α −52 20·4 β −52 28·0	−52 24·2	
17.	11 00 A.M.	R 7	α −52 32·1 β −52 23·4	−52 27·8	
17.	3 30 P.M.	R 4	α −52 34·0 β −52 13·6	−52 23·8	
21.	8 00 A.M.	R 4	α −52 29·9 β −52 18·6	−52 24·2	
21.	3 30 P.M.	R 4	α −52 29·7 β −52 19·9	−52 24·8	

Observations of Inclination. (Continued.)

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1842.	h m		° ′	° ′	
June 28.	8 00 A.M.	R 4	α −52 28·8 β −52 14·1	−52 21·5	Needles belonging to H.M.S. Erebus.
July 1.	3 30 P.M.	R 4	α −52 37·7 β −52 03·6	−52 20·7	
5.	8 00 A.M.	R 4	α −52 28·7 β −52 14·3	−52 21·5	
8.	3 30 P.M.	R 4	α −52 35·4 β −52 11·5	−52 23·5	
12.	8 00 A.M.	R 4	α −52 34·1 β −52 11·9	−52 23·0	
15.	3 30 P.M.	R 4	α −52 35·6 β −52 09·7	−52 22·7	
19.	8 00 A.M.	R 4	α −52 32·8 β −52 11·6	−52 22·2	
22.	3 30 P.M.	R 4	α −52 31·8 β −52 14·8	−52 23·3	
August 2.	8 00 A.M.	R 4	α −52 32·6 β −52 16·1	−52 24·3	
9.	8 00 A.M.	R 4	α −52 33·4 β −52 11·9	−52 22·6	
12.	3 30 P.M.	R 4	α −52 32·7 β −52 13·8	−52 23·2	
16.	8 00 A.M.	R 4	α −52 29·9 β −52 10·1	−52 20·0	
19.	3 30 P.M.	R 4	α −52 38·4 β −52 11·9	−52 25·2	
23.	8 00 A.M.	R 4	α −52 10·0 β −52 34·0	−52 22·0	
23.	9 00 A.M.	R 6	α −52 25·7 β −52 19·3	−52 22·5	
23.	10 00 A.M.	R 7	α −52 30·9 β −52 17·5	−52 24·2	
April 15.	8 00 A.M.	C 1	α −52 47·0 β −52 21·7	−52 34·3	Needles belonging to H.M.S. Terror.
15.	3 00 P.M.	C 1	α −52 46·1 β −52 24·9	−52 35·5	
19.	8 45 A.M.	C 1	α −52 43·3 β −52 20·2	−52 31·8	
19.	3 45 P.M.	C 1	α −52 42·8 β −52 21·6	−52 32·2	
June 15.	8 00 A.M.	C 1	α −52 40·4 β −52 24·4	−52 32·4	
15.	9 00 A.M.	C 2	α −52 37·8 β −52 20·9	−52 29·4	
15.	3 00 A.M.	C 1	α −52 39·9 β −52 23·4	−52 31·7	
15.	3 40 A.M.	C 2	α −52 35·4 β −52 23·2	−52 29·3	
July 26.	8 40 A.M.	C 1	α −52 44·9 β −52 23·5	−52 34·2	
26.	10 30 A.M.	C 2	α −52 38·6 β −52 15·3	−52 26·9	
August 17.	10 00 A.M.	C 1	α −52 50·4 β −52 21·0	−52 35·7	
17.	10 30 A.M.	C 2	α −52 36·2 β −52 14·1	−52 25·1	
23.	9 30 A.M.	C 1	α −52 39·9 β −52 24·9	−52 32·4	
23. 23.	11 00 A.M. 11 40 A.M.	C 2	α −52 33·8 β −52 19·2	−52 26·5	
				−52 26·2	General Mean.

From these observations we have the true inclination at these six stations as follows:—

	° ′
On ice, lat. −65 49. Long. 202 02 . .	79 39·5
On ice, lat. −63 23. Long. 210 02 . .	77 23·3
Hobarton	70 40·7
Sydney	62 49·1
New Zealand	59 31·9
Falkland Islands	52 26·2

The observations with R. F. 5, at the same stations, and at the same spots on shore, or on the ice, gave as follows:—

	On Ice. Lat. −65° 49′. Long. 202° 02′.	On Ice. Lat. −63° 23′. Long. 210° 02′.	Hobarton.	Sydney.	New Zealand.	Falkland Islands.
	° ′	° ′	° ′	° ′	° ′	° ′
Face East	−79 35·6	−77 15·5	−70 26·4	−62 46·3	−59 29·8	−52 32·9
Face West	−80 39·2	−78 20·3	−71 20·3	−63 44·3	−60 27·9	−53 34·7
Mean	−80 07·4	−77 47·9	−70 53·4	−63 15·3	−59 58·8	−53 03·8

We have thus the following index corrections:—

	′	′	′	′	′	′
Face East	− 3·8	− 7·8	−14·3	− 2·8	− 2·1	+ 6·7
Face West	+59·7	+57·0	+39·6	+55·2	+56·0	+68·5
Mean correction	+27 9	+24·6	+12·7	+26·2	+26·9	+37·6

and the difference of the results with the face east and face west as follows:—

′	′	′	′	′	′
63·6	64·8	53·9	58·0	58·1	61·8

From the signs and numerical values of the corrections of the *mean results* with R. F. 5, we may infer that the axis of rotation in this needle deviated from the centre of gravity in the longitudinal direction, so as to cause the south end of the needle slightly to preponderate. From the differences of the results with the face east and face west, it appears that there was also a small deviation in the axis of rotation from the centre of gravity in the perpendicular direction. In the results with the face east, these two sources of error partially counteracted each other, so that the index correction with the face east amounted at no time to more than a very few minutes.

The corrections which have been applied to the observations have been taken from the following table, in which the correction for −70° has been taken as −5′·8, and the change in the correction, corresponding to an increase of one degree in the south dip, as −0′5. In forming this table the determinations on land have been allowed a greater weight than the determinations upon the ice, the latter consisting of fewer observations, and being made probably under circumstances less favourable for this particular purpose.

Table of Index corrections for R. F. 5, face East, between −52° and −85°.

Inclination.	Correction.	Inclination.	Correction.
°	′	°	′
−52	+3·2	−69	− 5·3
−53	+2·7	−70	− 5·8
−54	+2·2	−71	− 6·3
−55	+1·7	−72	− 6·8
−56	+1·2	−73	− 7·3
−57	+0·7	−74	− 7·8
−58	+0·2	−75	− 8·3
−59	−0·3	−76	− 8·8
−60	−0·8	−77	− 9·3
−61	−1·3	−78	− 9·8
−62	−1·8	−79	−10·3
−63	−2·3	−80	−10·8
−64	−2·8	−81	−11·3
−65	−3·3	−82	−11·8
−66	−3·8	−83	−12·3
−67	−4·3	−84	−12·8
−68	−4·8	−85	−13·3

Index Correction of F. C. B. *for the Observations of Inclination in the Terror.*—The observations of inclination at sea in this ship were all made with the face of the instrument towards the east, and with the marked face of the needle towards the observer. We may examine the index corrections consequently in the same manner, and by comparison with the same complete determinations as in the case of the needle of the Erebus; confining the comparison however to the land stations, because F. C. B. was not observed with at either of the ice stations.

The inclinations taken with this needle were observed both direct and with the aid of deflectors; the deflectors employed were a spare needle as "deflector N" and "deflector S"; and the magnets of the apparatus, either used separately as "magnet N," or "magnet S," or conjointly as "magnets N S." From some instrumental accident, the inclinations observed with "deflector N" were always considerably in defect of the others when the face of the circle was east; with a corresponding excess with the face west, on the few occasions on shore when the observations were made in both positions. As the observations at sea were exclusively with the face east, it has been necessary on this account to consider separately those amongst them which were taken with "deflector N," and to obtain a distinct index correction for them. We will first examine the index corrections required for the direct observations, and for those with the other deflectors.

The observations with F. C. B. on shore at the four land stations, where the complete process for determining the true inclination was gone through with other needles, were as follows:—

		Hobarton.	Sydney.	New Zealand.	Falkland Islands.
		° ′	° ′	° ′	° ′
Observed . .	Face East	−70 17·3	−62 22·4	−58 50·6	−51 38·4
	Face West	−70 44·8	−62 56·5	−60 02·8	−52 57·2
Mean		−70 31·1	−62 39·5	−59 26·7	−52 17·8
True inclination		−70 40·7	−62 49·1	−59 31·9	−52 26·3
Index correction	Face East	−23·4	−26·7	−41·3	−47·9
	Face West	+ 4·1	+ 7·4	+30·9	+30·9
	Mean . .	− 9·7	− 9·6	− 5·2	− 8·5
Differences face East and West		27·5	34·1	72·2	78·8

The corrections of the *mean results* with F. C. B. at the four stations accord well within the limits of observation error. On examining the differences in the results with the face east and face west, and the corrections severally required in the two positions at the four stations, it appears probable that a very slight derangement of some part of the instrument took place between the observations at Sydney and those at the Bay of Islands, which caused the partial results with the face east and face west to diverge more from each other than they had done previously, but without affecting the mean results. A note which accompanied the observations to England shows that Captain Crozier considered that some slight change had taken place in the amount of the index correction with the face east, but was unable to assign its date or its cause. In the absence of any distinct evidence in these respects,—and in consideration of the insufficiency of the means of assigning the precise amount of the change,—I have preferred the employment of an arithmetical mean of the index corrections observed at the four stations (−35′) during the whole course of the voyage. The uncertainty arising from this source cannot amount to more than a very few minutes in any portion of the voyage.

For the index correction with deflector N we have,

	Hobarton.	Sydney.	New Zealand.	Falkland Islands.
	° ′	° ′	° ′	° ′
Face East . . .	−69 33·5	−61 36·7	−57 58·0	−50 54·4
Face West . . .	−71 25·9	−63 00·7	−60 12·3	−53 31·3
Mean	−70 29·7	−62 18·7	−59 05·1	−52 12·8
True inclination	−70 40·7	−62 49·1	−59 31·9	−52 26·3
Index correction, face East . .	−67·2	−72·4	−93·9	−91·9

Mean index correction, face East . . . . −81′

Elements of Calculation of the Intensity Observations.

1. ***With Weights.***—The observations of the intensity of the magnetic force, during the period now under consideration, were made in both ships with Mr. Fox's apparatus; those in the Erebus with the same circle which had been used in the previous voyage, and those in the Terror with a circle of the same size as that of the Erebus, being the property of Captain Crozier, and received by him at Van Diemen Island. The needle employed to show the angles of deflection in the Erebus, marked R. F. 5, was not the same which had been used for that purpose in the voyage of 1840–1841, namely, R. F. 4, which now in its turn was used as a deflector. The weights employed in deflecting the intensity needle were 1, 2, 3, 4, 5 and 6 grains: the angles of deflection obtained with one grain were however too small to yield results of the same satisfactory nature as those derived from the weights from two to six grains, and I have not therefore taken them into the account. The mounted needle in the Terror was marked F. C. B., a spare needle C being used as a deflector, in addition to the deflecting magnets belonging to the apparatus. The weights were 1, 1½, 2, 2½, 3 and 3½ grains.

At Hobarton we have the deflections occasioned by the constant weights on the needle of the Erebus, April 1841, as follows:—

	grs.	Deflection. °	′	Therm. °		grs.	Deflection. °	′	Therm. °
Face East.	2	13	02·8	60	Face West.	2	13	14·5	60
	3	19	37·2	60		3	19	55·5	60
	4	26	47·7	60		4	27	02·7	58
	5	34	23·5	60		5	34	51·5	58
	6	42	55·7	61		6	43	07·3	58

and in the needle of the Terror as follows:—

	grs.	Deflection. °	′	Therm. °		grs.	Deflection. °	′	Therm. °
Face East.	1	12	11·9	60	Face West.	1	11	42·0	60
	1½	18	29·4	60		1½	17	52·6	60
	2	25	13·7	60		2	24	15·6	60
	2½	31	43·0	60		2½	31	00·7	60
	3	39	02·3	60		3	38	42·3	60
	3½	46	51·3	60		3½	46	06·3	60

At Sydney, in July 1841, the deflections with the same weights were—

Erebus.

	grs.	Deflection. °	′	Ther. °		grs.	Deflection. °	′	Ther. °
Face East.	2	13	57·4	56	Face West.	2	14	32·6	64
	3	21	13·7	55		3	21	51·4	63
	4	29	09·2	55		4	29	32·1	64
	5	37	43·3	55		5	37	38·9	63
	6	46	51·7	55		6	47	32·4	63

Terror.

	grs.	Deflection. °	′	Ther. °		grs.	Deflection. °	′	Ther. °
Face East.	1	13	08·8	60	Face West.	1	12	44·1	60
	1½	20	02·0	60		1½	19	03·3	60
	2	27	00·7	60		2	26	01·2	60
	2½	34	25·2	60		2½	33	17·7	60
	3	42	06·9	60		3	41	35·2	60
	3½	51	13·5	60		3½	51	02·1	60

Taking 1·82 as the provisional value of the intensity at Hobarton (Phil. Trans. 1843, Part II. p. 186)*, we have its value at Sydney, by the needles of the two ships, as follows:—

Erebus.

grs.	Face East.	Face West.
2	1·703	1·662
3	1·687	1·667
4	1·683	1·680
5	1·680	1·704
6	1·698	1·688
	1·690	1·680
	1·685	

Terror.

grs.	Face East.	Face West.
1	1·691	1·674
1½	1·685	1·712
2	1·708	1·705
2½	1·692	1·709
3	1·709	1·715
3½	1·703	1·687
	1·698	1·700
	1·699	

At the Bay of Islands in New Zealand, in August and October 1841, the deflections were as follows:—

Erebus.

	August.				October.			
	Face East.		Face West.		Face East.		Face West.	
grs.	Deflection.	Ther.	Deflection.	Ther.	Deflection.	Ther.	Deflection.	Ther.
	° ′	°	° ′	°	° ′	°	° ′	°
2	14 59·3	59	15 23·3	60	14 43·2	68	15 11·1	64
3	22 47·5	59	23 17·9	59	22 45·0	70	23 17·2	64
4	30 55·0	59	30 26·9	59	30 30·6	70	31 29·2	65
5	40 10·5	58	40 52·0	60	39 59·3	70	40 51·0	65
6	50 38·1	58	51 26·0	61	50 35·0	71	51 38·7	65

Terror.

	August.				October.			
	Face East.		Face West.		Face East.		Face West.	
grs.	Deflection.	Ther.	Deflection.	Ther.	Deflection.	Ther.	Deflection.	Ther.
	° ′	°	° ′	°	° ′	°	° ′	°
1	14 03·2	59	13 24·3	59	13 51·7	64	13 26·8	64
1½	21 17·9	59	20 30·5	59	20 53·0	64	20 16·4	64
2	28 22·1	59	27 46·9	59	28 22·4	64	27 38·8	64
2½	36 50·7	59	35 43·0	59	37 05·6	64	35 45·1	64
3	44 58·3	59	44 38·7	59	45 02·2	64	44 47·7	64
3½	55 09·9	59	55 23·7	59	55 19·1	64	55 26·4	64

whence we have the intensity at the Bay of Islands, by the needles of the two ships, as follows:—

---

* 1·82 + e being the true value, in which e is a small correction to be determined hereafter, applicable to the whole series of observations depending on Hobarton as a primary station.

Erebus.

	August.		October.	
grs.	Face East.	Face West.	Face East.	Face West.
2	1·590	1·571	1·620	1·593
3	1·578	1·568	1·583	1·570
4	1·597	1·633	1·619	1·586
5	1·594	1·590	1·603	1·591
6	1·604	1·591	1·608	1·588
	1·593	1·591	1·607	1·586
	1·592		1·596	
	1·594			

Terror.

	August.		October.	
grs.	Face East.	Face West.	Face East.	Face West.
1	1·584	1·592	1·606	1·588
1½	1·601	1·595	1·620	1·616
2	1·633	1·605	1·633	1·613
2½	1·596	1·607	1 587	1·606
3	1·622	1·619	1·621	1·616
3½	1·618	1·594	1·616	1·594
	1·609	1·602	1·614	1·605
	1·605		1·609	
	1·607			

At Port Louis in the Falkland Islands, in July and August 1842, the deflections were—

Erebus.

	April.				August.			
	Face East.		Face West.		Face East.		Face West.	
grs.	Deflection. ° ′	Ther. °	Deflection. ° ′	Ther. °	Deflection. ° ′	Ther. °	Deflection. ° ′	Ther. °
2	18 31·1	45	18 50·4	42	17 57·1	37	18 32·9	39
3	27 42·7	45	28 30·0	42	27 43·3	37	28 26·6	40
4	37 58·5	43	38 51·0	41	37 40·4	37	39 05·3	40
5	48 55·9	43	51 27·9	41	49 31·4	38	51 19·2	40
6	66 49·8	43	68 40·3	41	67 23·4	38	69 35·7	40

Terror.

	April.				July.				August.			
	Face East.		Face West.		Face East.		Face West.		Face East.		Face West.	
grs.	Deflection. ° ′	Ther. °	Deflection. ° ′	Ther. °	Deflection. ° ′	Ther. °	Deflection. ° ′	Ther. °	Deflection. ° ′	Ther. °	Deflection. ° ′	Ther. °
1	16 56·5	43	16 14·1	43	16 51·2	41	16 26·1	41	17 00·4	38	16 15·4	38
1½	25 36·6	43	24 36·9	43	25 34·3	41	24 27·9	41	25 37·3	38	24 30·1	38
2	34 47·2	43	33 44·9	43	34 47·8	41	33 49·5	41	34 24·4	38	33 57·8	38
2½	45 34·1	43	44 31·3	43	45 29·7	41	44 17·1	41	45 20·1	38	44 32·3	38
3	57 39·1	43	58 17·8	43	57 48·7	41	58 19·5	41	57 43·6	38	57 35·7	38

whence we have the intensity at Port Louis, by the needles of the two ships, as follows:—

Erebus.

	April.		August.	
grs.	Face East.	Face West.	Face East.	Face West.
2	1·291	1·288	1·330	1·306
3	1·311	1·296	1·310	1·299
4	1·331	1·315	1·339	1·309
5	1·361	1·326	1·347	1·329
6	1·345	1·332	1·339	1·324
	1·328	1·311	1·333	1·313
	1·320		1·323	
	1·322			

Terror.

	April.		July.		August.	
grs.	Face East.	Face West.	Face East.	Face West.	Face East.	Face West.
1	1·316	1·316	1·323	1·301	1·311	1·315
1½	1·331	1·338	1·333	1·345	1·331	1·344
2	1·356	1·342	1·355	1·339	1·369	1·335
2½	1·336	1·334	1·338	1·339	1·341	1·333
3	1·353	1·333	1·350	1·333	1·352	1·344
	1·338	1·332	1·340	1·331	1·341	1·334
	1·335		1·336		1·337	
			1·336			

es the four land stations at which the intensities shown by the needles of the
ips have been thus compared, we have also one ice station in lat. −65° 47′,
202° 08′, at which similar comparisons may be instituted. The deflections and
ities were as follows:—

Erebus.

Face East.

grs.	Deflection.	Ther.	Intensity.
2	12° 13′·0	50°	1·940
3	18 32·4	54	1·921
4	24 49·3	54	1·952
5	32 02·4	54	1·936
6	39 31·4	55	1·946
			1·939

Terror.

Face East.

grs.	Deflection.	Ther.	Intensity.
1	11° 25′·4	53°	1·940
1½	17 08·3	53	1·957
2	23 02·9	53	1·979
2½	29 16·2	53	1·955
3	36 17·4	53	1·935
3½	43 23·5	53	1·932
			1·950

Collecting these several results in one view, we have as follows:—

	Erebus.	Terror.	Difference. (Erebus in defect.)
Intensity at Hobarton	1·82	1·82	
Intensity at Sydney	1·685	1·699	·014 or 8 parts in 100
Intensity at the Bay of Islands	1·594	1·607	·013 or 8 parts in 10
Intensity on ice, lat. −65° 49′, long. 202° 02′	1·939	1·950	·011 or 7 parts in 10
Intensity at Port Louis, Falkland Islands	1·322	1·336	·014 or 10 parts in 1

The difference between the results given by the needles of the two ships, tho
small, is so consistently shown at all the stations during the voyage, that we ca
hesitate to attribute it to the occurrence of a change of corresponding amount i
magnetism of one needle or the other, between the observations at Hobarton in
1841, and those at Sydney in July of the same year. If we further compa
intensities observed at sea by the two ships on the passage from Hobarton to S
we find that a similar difference prevails in them; and we are therefore led
conclusion, either that the needle of the Terror gained, or that the needle
Erebus lost, a very small portion of magnetism, in the period between the
tions at Hobarton in April 1841, and the departure of the Expedition from
in the following July. Now experience has shown that a loss of magnet
unfrequent occurrence, whilst a gain is extremely rare, happening only, as
know, from such an accident as the contact of a needle with a more power
than itself. We may therefore conclude with great probability that the n
Erebus sustained a small loss of magnetism between April and July 1841, a
all the observations of the voyage, causing the intensities derived with it, *w*
in reference to the angles of deflection observed at Hobarton in April 18
to be increased about one hundredth part, or more precisely 8 parts in

to bring them into strict relation with 1·82, taken as the value of the force at Hobarton. This correction being applied, all the intensities observed throughout the voyage by the two ships are in accordance (subject only to errors of observation), forming a consistent series of relative determinations, resting on 1·82 and 1·336, assumed provisionally as the values of the intensity at Hobarton and Port Louis, the commencing and concluding stations of the series. The correction is made in the Table which exhibits the intensities observed on board the two ships, and the geographical positions to which they belong; it is also made in the results inserted in the Map. The correctness of the values assumed at the base stations, 1·82 at Hobarton and 1·336 at Port Louis, remains to be proved by absolute determinations which have yet to be made at those two stations. The absolute intensities observed by the Expedition itself, with the instruments and according to the method prescribed in the instructions of the Royal Society, certainly have not the necessary precision. In the preceding Number of these Contributions are stated the results of five determinations which were obtained by Captain Ross at Hobarton in 1840 and 1841, with the 15-inch magnets of his observatory magnetometers; and of twenty-two determinations obtained by Lieut. Kay at the magnetic observatory at that station, with similar instruments, in 1841 and 1842. Captain Ross's mean result was 4·573, the partial results varying from 4·491 to 4·626. Lieut. Kay's mean result in 1841 was 4·553, the partial results (ten in number) varying from 4·509 to 4·601; and in 1842 4·513, the partial results (twelve in number) varying from 4·443 to 4·568. In 1843 Lieut. Kay received the *auxiliary apparatus* supplied in compliance with the *revised instructions* of the Royal Society, published in 1842. The magnets of this apparatus were 12 inches in length. The following Table exhibits the results obtained with this instrument in thirteen determinations made with it, between June 23rd and July 1st, 1843. Each determination is deduced from two series of observations of deflection; in the first six instances the distances were 4·505 and 6·005 feet; in the remainder, 4·0 and 5·3 feet. The moment of inertia of the deflecting magnet was computed from the length, breadth and mass of the bar.

June 23.	4·509	June 27.	4·557
24.	4·515	28.	4·505
24.	4·528	28.	4·504
26.	4·510	29.	4·549
26.	4·523	29.	4·527
27.	4·583	30.	4·466
		July 1.	4·479

Mean of the 13 determinations 4·520

Here also it is obvious, from the discrepancy of the partial results, that the angles of deflection afforded by these magnets at the prescribed distances, viz. the least distance being not less than four times the length of the bar, were still too small; and that before any final conclusion be arrived at, it is desirable that we should await the results which will be obtained with the smaller apparatus described by Lieut. **Riddell** in his "Magnetical Instructions for the use of Portable Instruments," &c. In this apparatus the suspended and deflecting magnets are respectively 3·0 and 3·67 inches in length. Meanwhile we may derive, as a provisional value, the arithmetical mean of the four mean results already stated; allowing to each an equal weight, we have,

Ross, in 1840–1841,	15-inch magnets,		4·573	Mean 4·54
Kay, in 1841,	do.	do.	4·553	
Kay, in 1842,	do.	do.	4·513	
Kay, in 1843,	12-inch magnets,		4·520	

which, with the other necessary data stated in the preceding Number of these Contributions, would give the value of the total intensity at Hobarton 1·81 to 1·372 in London*.

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* Since these pages were written I have received the details of the observations of ten distinct determinations of the absolute horizontal intensity at the magnetic observatory at Hobarton, made in August 1843 with deflecting and suspended magnets respectively of 9·18 inches and 7·50 inches in length. The deflecting distances were the same throughout, being 3·2893 and 4·3393 feet. The calculation of these observations not having been yet received from Lieut. Kay, the results have been computed by Lieut. Riddell, R.A., F.R.S., so far as the materials hitherto furnished permit. They give the value of X';—being the absolute horizontal intensity (X), uncorrected for the difference in the magnetic moment of the deflecting bar produced by the earth's inducing action in the different positions in which the bar is placed in the experiments of deflection and in those of vibration; viz. 1° perpendicular to the magnetic meridian, and 2° in the plane of the meridian. We owe the suggestion of a correction due to this cause to Dr. Lamont: but the necessary data for computing it, for the particular bars employed by Lieut. Kay on this, or on the former occasions, have not yet been received. Observations made at the Cape of Good Hope and at Woolwich, with similar bars, have given results which show that the correction may possibly prove to be of nearly the same amount for the larger and smaller bars, in which case the relative values will be but little affected, and we may estimate that the value of X at Hobarton will be about 0·02 less than X'. In the expression which has been employed in these Contributions for the absolute horizontal intensity (1·82+e at Hobarton and 3·72+e at London, e being a small quantity to be supplied hereafter), the correction here referred to will form a portion of e. The following Table exhibits the abstract of the observations made in August 1843 with 9·18 and 7·50 inch bars.

Gottingen Mean Time.	Deflecting Magnet.			Values of X'.	Bifilar Magnetometer. k=000229. q=000224.	
	No.	Value of m'.	Temperature during deflection.		Reading.	Temp.
d h						
1843. Aug. 20 19·0	9·18 inch.	6·256	54°·6	4·5052	165·1	52°·0
21 11·5	9·18 inch.	·259	49·6	·5034	168·6	49·1
21 16·5	9·18 inch.	·251	51·9	·5043	165·3	49·1
21 19·5	9·18 inch	·261	53·7	·4993	168·3	50·0
22 11·0	9·18 inch.	·227	48·0	·5177	165·4	49·3
22 19·5	9·18 inch.	·243	54·5	·5025	164·6	50·7
23 10·8	9·18 inch.	·259	50·7	·4884	161·0	51·2
23 18·1	9·18 inch.	·244	52·4	·5005	162·2	51·0
23 19·1	9·18 inch.	·240	52·0	·4982	163·9	51·3
25 11·4	9·18 inch.	·252	49·4	·4953	165·3	51·5
		6·249	51·7	4·5015	165·0	50·5

The mean value of the results, 4·501, is considerably different from the mean deduced in the text

At the Falkland Islands there were two determinations of the absolute horizontal intensity made by Captain Ross at the Magnetic Observatory at Port Louis, one in September 1842, being 6·87, and a second in November of the same year, being 6·32. They were both made with 15-inch magnets; the angles of deflection were observed at four distances, but amounted only to 56′·8, 31′·9, 21′·4, and 12′·9 in the first experiment, and to 1° 49′·9, 1° 01′·6, 41′·5, and 25′·1 in the second experiment.

These values of the horizontal intensity would give that of the total intensity at Port Louis respectively 1·609 and 1·367. It is obvious that we can draw no conclusion whatsoever from these numbers, and that we must wait for the confirmation or correction of the value given by the needles of Mr. Fox's instrument, until absolute determinations can be procured with instruments capable of affording more satisfactory results. Steps have been taken to obtain such determinations at the Falkland Islands from Captain Sullivan, R.N., and at Sydney and New Zealand from the Surveying Expedition under Captain Blackwood, R.N.; when these arrive, we may learn whether any and what final correction will require to be applied to the intensities now provisionally deduced from the observations with Mr. Fox's needles, in the Erebus and Terror. We may expect to receive these determinations before the time when the results now presented to the Royal Society will have to be combined with those of the preceding and succeeding years, in a general calculation of the magnetic lines in the southern hemisphere.

2. *With Deflectors.*—In the Erebus, the spare needle R. F. 4 was employed,—as "deflector S," with its south pole opposite to the division of the circle which the south pole of the mounted needle had previously indicated as the dip;—and as "deflector N," with its north pole similarly applied to the opposite division of the circle. The angles of deflection varied in different localities during the voyage, in round numbers as follows:—Deflect. S from 52° to 71°; and deflect. N from 49° to 67°. For obtaining the equivalent weights to the deflecting force of the deflectors at these angles, we have the comparative observations with deflectors and weights at Hobarton, Sydney, New Zealand, the Falkland Islands, and on the ice in lat. —65° 47′, long. 202° 08′. The angles of deflection caused by the weights have been already stated;

the preceding observations; yet from the improvement which it is natural to suppose practice must have made in the observers, and from the reduced discrepancies of the partial results with the smaller bars, the mean of the ten results in August 1843 would seem entitled to a preference over the earlier and more numerous results. Judging by what has been done at Woolwich with the 2·45 and 3 inch magnets, and at the Cape of Good Hope with 3·0 and 3·67 inch, we may expect with them a still further and considerable reduction in the discrepancies of the partial results; but it would not be safe, with the comparisons which we have now before us, to feel full confidence that there will be no apparently constant or systematic difference between the results of the larger and smaller bars. Reviewing the whole subject, we can as yet, therefore, only consider ourselves as being in progress towards such accuracy in determining the ratio of the intensity at different places by the absolute method, as shall be superior to that with which it was previously obtained by the employment of well-selected needles in relative determinations.

those by the deflectors, with the equivalent weights deduced from the comparison, are collected in the following Table.

Station.	Date.	Intensity deduced by weights.	Angles of deflection by		Equivalent weights.	
			Def. S.	Def. N.	Def. S.	Def. N.
			° ′	° ′	grs.	grs.
Hobarton	April 1841	1·82	56 28·6	53 02·6	7·39	7·08
Sydney	July 1841	1·685	59 10·2	55 37·0	7·05	6·77
New Zealand....	Aug. and Oct. 1841	1·594	61 46·9	57 59·0	6·84	6·58
On ice	January 1842	1·939	54 03·1	50 35·0	7·65	7·30
Falkland Islands .	April and Aug. 1842	1·322	71 11·8	67 10·3	6·10	5·93

By projecting these angles and weights, and proceeding in the manner described in the Third Number of these Contributions *, the values of w' in the following Table were obtained for each deflector, corresponding to each angle of deflection v'; and employing these values of w', the intensities I' entered in the general table of observations have been computed by the formula

$$I' = \frac{1{\cdot}82 \sin 56^\circ\, 28'{\cdot}6}{7{\cdot}39} \cdot w' \operatorname{cosec} v' = 2{\cdot}053 w' \operatorname{cosec} v'.$$

Besides the observations with the spare needle R. F. 4, employed as a deflector, angles of deflection were occasionally observed with the magnets N and S, belonging to the apparatus of the Erebus, used conjointly; their magnetism, however, was so much inferior to that of R. F. 4, that, even when both were used together, their joint effect was less than the half of either pole of R. F. 4; their results would consequently be much inferior in precision to those of R. F. 4, and I have not therefore employed them.

Def. S.						Def. N.					
v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.
°	grs.	°	grs.	°	grs.	°	grs.	°	grs.	°	grs.
52	7·87	59	7·11	66	6·47	49	7·49	56	6·76	63	6·19
53	7·76	60	7·01	67	6·39	50	7·38	57	6·67	64	6·13
54	7·65	61	6·91	68	6·31	51	7·27	58	6·57	65	6·06
55	7·54	62	6·82	69	6·24	52	7·17	59	6·48	66	6·00
56	7·43	63	6·73	70	6·17	53	7·07	60	6·40	67	5·94
57	7·32	64	6·64	71	6·10	54	6·97	61	6·33		
58	7·21	65	6·55	72	6·03	55	6·86	62	6·26		

In the Terror, the spare needle marked C was employed both as "deflector N" and "deflector S." The magnets belonging to the apparatus were also used, N separately, and N and S conjointly. Observations were also occasionally made with magnet S, but its magnetism was so feeble, and the deflections obtained with it consequently so small in comparison with the others, that the results are not entitled to the same confidence, and have not therefore been taken into the account. The equivalent weights have been obtained, as in the Erebus, from the comparative observations with weights and deflectors at Hobarton, Sydney, New Zealand, the Falkland

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* Philosophical Transactions, 1842, Art. II.

Islands, and on the ice in lat. −65° 47′, long. 202° 08′. I have also, in the case of the Terror, availed myself of a comparison of the weights and deflectors made on the 3rd, 4th and 5th of December 1841, at sea, when the weather was extremely favourable, and the ship did not materially change her position. From the observations on these days we have as follows:—

December 1841.	Intensity deduced by weights.	Angles of deflection by			
		Def. N.	Def. S.	Mag. N.	Mag. N S.
		° ′	° ′	° ′	° ′
3 A.M.	1·783	36 55·9	34 06·7	30 44·1	40 52·8
3 P.M.	1·778	36 51·6	34 06·3	30 46·1	40 45·8
4	1·773	36 { 41·8 44·7	34 22·0	30 48·7	40 56·3
5	1·779	36 18·3	34 29·4	30 46·1	40 54·9
Mean ..	1·778	36 42·5	34 16·0	30 46·2	40 52·5

The several comparisons from which the equivalent weights are derived, together with the weights so derived, are collected in the following Table.

Station.	Date.	Intensity deduced by weights.	Angles of deflections by				Equivalent weights.			
			Deflector N.	Deflector S.	Magnet N.	Magnets N S.	Deflector N.	Deflector S.	Magnet N.	Magnets N S.
			° ′	° ′	° ′	° ′	grs.	grs.	grs.	grs.
Hobarton	April 1841 ..	1·820	36 00·6	33 23·0	30 14·0	40 05·5	2·793	2·613	2·391	3·059
Sydney	July 1841 ..	1·699	38 05·9	35 15·7	31 47·2	41 45·3	2·736	2·560	2·336	2·953
New Zealand ..	Aug. and Oct. 1841	1.608	39 36·8	36 57·8	32 50·8	42 58·4	2·675	2·525	2·276	2·861
At Sea	Dec. 3, 4 and 5, 1841	1·778	36 42·5	34 16·0	30 46·2	40 52·5	2·773	2·613	2·374	3·036
On Ice	Jan. 16, 1842	1·949	33 47·6	31 16·1	28 52·7	38 45·7	2·829	2·640	2·456	3·184
Falkland Islands	April, July and Aug. 1842	1·336	44 38·2	41 57·1	35 59·0	46 14·0	2·442	2·324	2·042	2·510

The equivalent weights for each deflector, and for each half degree of deflection, have been obtained in the manner already described, for the angles of deflection and equivalent weights in the preceding Table, and are subjoined; by their aid the intensities I′ entered in the general table of observations have been computed by the formula

$$I' = \cdot 3832 w' \operatorname{cosec} v'.$$

Def. N.				Def. S.				Magnet N.				Magnets NS.			
v′.	w′.	v′.	w′.	v′.	w′.	v′.	w′.	v′.	w′.	v′.	w′.	v′.	w′.	v′.	w′.
° ′	grs.	° ′	grs.	° ′	grs.	° ′	grs.	° ′	grs.	° ′	grs.	° ′	grs.	° ′	grs.
33 00	2·840	39 30	2·682	31 00	2·644	37 30	2·504	28 00	2·482	34 30	2·166	37 00	3·268	43 30	2·816
33 30	2·834	40 00	2·660	31 30	2·639	38 00	2·485	28 30	2·464	35 00	2·126	37 30	3·240	44 00	2·766
34 00	2·826	40 30	2·638	32 00	2·634	38 30	2·464	29 00	2·446	35 30	2·085	38 00	3·210	44 30	2·714
34 30	2·817	41 00	2·615	32 30	2·627	39 00	2·444	29 30	2·426	36 00	2·040	38 30	3·180	45 00	2·660
35 00	2·809	41 30	2·593	33 00	2·619	39 30	2·423	30 00	2·406			39 00	3·148	45 30	2·604
35 30	2·800	42 00	2·571	33 30	2·611	40 00	2·403	30 30	2·387			39 30	3·114	46 00	2·544
36 00	2·790	42 30	2·548	34 00	2·602	40 30	2·382	31 00	2·367			40 00	3·081	46 30	2·460
36 30	2·777	43 00	2·524	34 30	2·591	41 00	2·361	31 30	2·346			40 30	3·049		
37 00	2·765	43 30	2·488	35 00	2·580	41 30	2·341	32 00	2·323			41 00	3·016		
37 30	2·753	44 00	2·473	35 30	2·567	42 00	2·321	32 30	2·297			41 30	2·981		
38 00	2·738	44 30	2·448	36 00	2·554			33 00	2·268			42 00	2·944		
38 30	2·721	45 00	2·423	36 30	2·538			33 30	2·236			42 30	2·905		
39 00	2·702			37 00	2·523			34 00	2·203			43 00	2·863		

General Remarks.—If we take a general view of the magnetic DECLINATION in the southern hemisphere, particularly in the best-known portion of it, comprised between the tropics and the Antarctic Circle, we find that the phenomena present the same obvious and decided features of a duplicate system as do those of the northern hemisphere. If, following any of the geographical parallels, we carry our attention round the hemisphere, we find it divided into four spaces, in which opposite characteristics in regard to the direction of the needle alternately present themselves. In two of the spaces the change in the pointing of the needle, as the space is traversed in the direction of the parallel, is continuous and progressive towards the west, and in the other two continuous and progressive towards the east. If, for example, commencing with the meridian of 30° E. or thereabouts, we trace the parallel of $-45°$ round the hemisphere, always proceeding in an easterly direction till we return to the meridian at which we began, we shall find that we first pass through a space in which the direction of the north end of the needle becomes progressively more and more *easterly*, either by the decrease of westerly or increase of easterly declination; we next pass into a second space, on entering which the continuity is broken, the progressive movement of the north end of the needle towards the east is arrested, and its direction becomes now more and more *westerly* as we advance; thence we pass, successively, into a third space which has the same characteristic as the first, and into a fourth which has the same as the second.

The spaces here spoken of must be distinguished from those which are characterized by the exclusive prevalence of either east or west declination: they have a more simple and pure magnetical relation, implying the predominance within each space of one or the other of the two systems of magnetic forces which govern the direction of the needle. It may happen, or it may not happen, that in one of these spaces the direction of the needle may coincide in some point or points with the *geographical* meridian; when this occurs, the space will comprise both east and west declination; when it does not happen, the declination throughout the space will be exclusively east or exclusively west as the instance may be: but in either case, the change in the direction of the needle is always continuous and uniform in character throughout the space. It is well known that if the magnetic declination be computed on the supposition of a single central magnetic axis, there will be found two, and only two such spaces in each hemisphere. The systematic discordance which the declinations in the *northern* hemisphere presented when compared with the declinations so computed, and their agreement with the phenomena deducible from a double system of forces, led HALLEY to embrace the latter hypothesis. The declinations in the southern hemisphere present an arrangement strictly analogous to that in the northern, and conduct to the same conclusion, be that conclusion what it may.

If, with HALLEY, we view the declinations in the Southern Pacific as principally influenced by the weaker system of forces, or by that to which is also to be ascribed the high intensity of the magnetic force in the same quarter, we should be prepared to expect that if the geographical limits of the adjacent spaces, having the characteristics referred to, were determined at different epochs, the alteration in the position of the spaces, if any, would show the existence of a secular change in the system itself; that it would indicate the direction of such change; and, if the intervals were sufficiently long in reference to the precision with which the determinations were made, the average rate of the movement of translation might also be inferred.

In this view a knowledge of the geographical position of the limiting lines, or of lines drawn so as to separate one of these spaces from the next, may have a particular value. In the part of the Pacific Ocean which is now referred to, the *separating lines*, as for distinction they may be called, coincide nearly in direction with geographical meridians, and are therefore crossed nearly at right angles by vessels pursuing a course from east to west, or from west to east. Prior to our own times, the epoch of Captain Cook's voyages is perhaps that in which the observations of the declination in the Southern Pacific may be regarded with the most confidence. The determinations of that period have been collected by M. Hansteen into a map, of which he assigns the year 1770 as the mean epoch. It is one of those published in the Atlas of the Magnetismus der Erde, and comprehends the results obtained by Byron, Carteret, Wallis, Cook in three voyages, Ekeberg also in three voyages, and Abercrombie. If in this map we draw lines separating the spaces which have the opposite magnetic characteristics referred to, and compare them with the corresponding lines which we may draw in Erman's map of the Declination in 1827–1830, published in the Magnetic Instructions of the Royal Society, we find an effect of secular change very distinctly shown in the altered position of the separating lines. These lines, A and B, are drawn in the accompanying Plate*, where the two epochs, 1770, and 1827–1830, are brought into comparison. In the map of 1827–1830, the separating lines occupy a considerably more westerly position than in the earlier map, the difference amounting to about 10° of longitude. Hence we are led to the conclusion, that the spaces in the Southern Pacific, distinguished by certain magnetic characteristics, undergo a movement of translation, of which the general direction is from east to west. This direction is the opposite to that in which the change is known to take place in the corresponding quarter in the northern hemisphere (viz. in the Siberian quarter), where the secular movement is from west to east.

We are not without earlier, though possibly it may be supposed less precise, evidence of the effect of secular change in the Southern Pacific. From Halley's chart of the variation lines for 1700, we are enabled to draw the separating line B for that epoch, when we find it to have been between the longitudes of 305° and 310°. In a still earlier map drawn by Hansteen for the year 1600 (Magnetismus der Erde, Atlas, No. 1), representing the observations of the very able and scientific navigators of that period, we find the position of the same line to have been about 333° of east longitude.

In the observations of Captain Ross's voyage, we have the most recent evidence of the progressive westerly movement of the magnetic phenomena in the Southern

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* Plate XII.

Pacific. The separating lines A and B, deducible from the observations in 1842, are seen in the Plate to be in both cases considerably to the west of those derived from the observations of 1827–1830.

The whole body of evidence therefore, from the earliest observations to the latest, is consistent in showing a progressive movement to the westward of the spaces in the Southern Pacific, characterized by certain magnetic peculiarities, which in HALLEY's view indicated the proximity and predominance of the weaker system of forces. It is worthy of notice that the rate of progression, deduced from the changes of position shown at the several epochs, differs much less from a uniform rate than might have been anticipated from the nature of the evidence we possess, even supposing the actual rate to have been uniform in nature; whilst the magnitude of the whole change which appears to have taken place since the phenomenon became the subject of observation, in round numbers 50° of longitude in two centuries and a half, can scarcely fail to fix the attention. These are facts which, when the true physical causes of the magnetism of the globe shall occupy the earnest attention of philosophers, will probably attain an importance which at present perhaps we scarcely sufficiently estimate. But an endeavour to place distinctly before our minds facts of which the explanation must be deemed an essential condition of a satisfactory solution of this great problem, may not be without its use even at the present time. It may be also useful to call the attention of navigators to the value which may hereafter attach to determinations which may be made with instruments which are on board every ship, and in constant employ for the ordinary purposes of navigation. The position of the lines separating the spaces which have been the subject of discussion, has the advantage of being even more easily determined by observations on board ship than that of any particular declination line; in crossing them, the declination, if previously decreasing, will then begin to increase, and if previously increasing will begin to decrease; the determination is therefore independent of compass error, which is a much more prevalent source of error than is generally supposed; and if the ship's course be steady for some days together, which in the latitudes in question is very frequently the case, it is also in a great measure independent of the disturbance occasioned by the ship's iron. A very cursory inspection of the general table of the declinations observed by the Erebus and Terror suffices to show that they must have crossed the separating line (A) about the 15th of March 1842, when their latitude was about $-59°$ and longitude 221°; and the line (B) about the 27th or 28th of the same month in latitude about $-59°$, and longitude 275°[*].

Should the circumstance occur that one of the separating lines in the course of its progressive change of place should pass over a magnetic observatory, the epoch of its passage would be precisely determined. There is some reason for believing that such an event is now taking place at the Cape of Good Hope. If we examine **Erman**'s map of the Declination in 1827–1830, published in the magnetic instructions of the Royal Society, we find one of the separating lines in the neighbourhood of the Cape of Good Hope, and if we compare this map with those of earlier epochs, we find the position of that line progressively more and more to the east as we ascend in the order of time. Hence we should be led to expect that about this period it might be found to pass over the meridian of the Cape. The observations which have been made daily at the magnetic observatory at the Cape, since its establishment in 1841, give reason to believe that the westerly declination which had been increasing for above two centuries, attained its maximum in the year 1842 or 1843. In April 1841 the declination was 29° 05′ west, in and April 1844 29° 06′ west[*]. The earliest observations at the Cape with which I am acquainted, are those of **Davis** in 1605, and **Keeling** in 1609. (Purchas, Book iv. ch. 6. § 1. and Book iii. ch. 6. § 4.) According to these observations the declination in 1605 was 0° 30′ east, and in 1609 0° 12′ west[†]. The line of no declination probably therefore passed over the Cape about the year 1607, and in 235 years the westerly declination has increased from 0° to 29°, (omitting the odd minutes,) or at an annual average rate of $7'\cdot4$. Observations at several intermediate epochs show that the progression of this change was at least not very far from being an uniform one. If we divide the whole period into four equal parts, we should have

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[*] The line A passes through the culminating points of the southerly inflexion of the declination lines, of which the present position is shown in the Declination Map at the close of this paper to be about 220° east longitude. The line B passes through the culminating points of the northerly inflexion of the declination lines about the longitude of 276°.

	°	′	
In the year 1607	0	0	
In the year 1666	7	15	W.
In the year 1725	14	30	W.
In the year 1784	21	45	W.
In the year 1843	29	0	W.

In the appendix of **Hansteen**'s Magnetismus der Erde, p. 24, we have the record of actual observations as follows :—

	°	′	
In the year 1667	7	15	W.
In the year 1724	16	27	W.
	16	18	W.
In the year 1780	22	16	W.

We may therefore conclude that the westerly declination at the Cape, which for above 200 years had increased at an average rate of about $7'\cdot4$ a year, or a degree in about eight years, has been for the last three years nearly stationary, having arrived at a maximum of 29° and a few minutes about the year 1843; and that a decreasing progression may now be expected[‡]. Ships passing the Cape, on a voyage to the east, will find that the westerly variation, which increases the whole way from the Brazils to about the meridian of the Cape, begins there to diminish, and continues to diminish, passing into easterly variation increasing, for above 100 degrees of longitude east of the Cape. The separating line which now passes through the Cape divides spaces distinguished by opposite magnetic characteristics; on the west side of the Cape the north end of the needle moves to the west, and on the east side to the east, as east longitude increases.

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[*] The observations at the magnetic observatory at the Cape of Good Hope, preparing for the press, will show the mean declination in each month of the years referred to.

[†] See also, for the latter observation, **Hansteen**'s Magnet. der Erde. Anhang. S. 146.

[‡] Captain **FitzRoy** observed 28° 30′ in 1836; at that epoch, consequently, the maximum had not been reached. Sir **Edward Belcher**, in 1842, observed 29° 13′.

The maps which exhibit the results of the observations in the two ships, of the Declination, Inclination and Intensity, in the voyage of 1841–1842, and the isogonic, isoclinal, and isodynamic lines traced approximately in conformity with them, are a continuation of the maps published in No. V., which embodied in a similar manner the results of the preceding voyage. The results in the Erebus are distinguished from those in the Terror by a different character, for the purpose of permitting the degree of accordance in the two series of independent determinations to be readily judged of by the eye. These maps afford the best reply to those who have expressed doubts of the success of observations of the inclination and intensity made at sea.

Magnetic lines, drawn from observations made in parts of the globe to which observation had not previously extended, are the proper test by which we may judge of the degree of approximation with which the values of the numerical elements have been obtained in a general mathematical theory of terrestrial magnetism, such as M. Gauss's. The portion of the observations of the Antarctic Expedition which has been placed before the Royal Society in No. V. and in the present number of these Contributions, permits us already to form some conclusion on this point. Plate XIII. exhibits the lines of one of the magnetic elements, i. e. the intensity, computed by M. Gauss's theory, and drawn in Plates XVIII. and XIX. of the Atlas des Erdmagnetismus, compared with the lines which are the direct results of observation.

The very imperfect resemblance between the two systems of lines is of course no impeachment of the sufficiency of the theory, with corrected numerical elements, to represent the natural phenomena in parts of the globe which observation may not have reached. The degree of approximation to which it will do this must depend upon the extent and correctness of the observation-basis from whence the numerical elements are derived, and upon the order of the magnitudes comprehended in the calculation.

The evidence which the plate affords, that the calculations in the elaborate work referred to differ so widely from the facts in the southern latitudes, shows how much observations were wanting in those latitudes for the purpose of perfecting the theory; and is an ample justification (if indeed any justification were necessary) of the exertions which the last few years have witnessed to obtain them.

Since these pages were written I have received from Mr. Archibald Smith the following note. Regarding it as a continuation of the memorandum with which he

"By the introduction of the same quantities, the equations numbered from (4.) to (14.) in the former memorandum become

$$\frac{H'}{A'H} = \cos\zeta\cos\zeta' + b\sin\zeta\sin\zeta' + L\cos\zeta' + M\sin\zeta' \quad . \; . \; . \quad (4.)$$

$$(\cos\zeta + L)\sin\zeta' = (b\sin\zeta + M)\cos\zeta' \,; \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (5.)$$

and representing $\zeta - \zeta'$, or the deviation, by δ,

$$\sin\delta = L\sin\zeta' - M\cos\zeta' + (1-b)\sin\zeta\cos\zeta' \; . \; . \; . \; . \; . \; . \; . \; . \quad (6.)$$

$$= \frac{2}{1+b}L\sin\zeta' - \frac{2}{1+b}M\cos\zeta' + \frac{1-b}{1+b}\cdot\sin(\zeta+\zeta') \; . \; . \; . \; . \quad (7.)$$

$$\tan\zeta' = \frac{b\sin\zeta + M}{\cos\zeta + L} \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (8.)$$

$$c\cos\zeta + N = (b\sin\zeta + M)\operatorname{cosec}\zeta'\tan\theta' \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (9.)$$

$$= (\cos\zeta + L)\sec\zeta'\tan\theta' \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (10.)$$

$$= \sqrt{(\cos\zeta + L)^2 + (b\sin\zeta + M)^2}.\tan\theta' \; . \; . \; . \; . \; . \quad (11.)$$

$$\tan\theta' = \frac{c}{b}\cdot\frac{\cos\zeta + \frac{1}{c}N}{\sin\zeta + \frac{1}{b}M}\sin\zeta' \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (12.)$$

$$= c\frac{\cos\zeta + \frac{1}{c}N}{\cos\zeta + L}\cdot\cos\zeta' \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (13.)$$

$$= \frac{c\cos\zeta + N}{\sqrt{(\cos\zeta + L)^2 + (b\sin\zeta + M)^2}}. \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (14.)$$

"Equation (7.) may also be put under the form

$$\sin\delta = \frac{2}{1+b}\sqrt{L^2+M^2}\sin(\zeta'-\mu) + \frac{1-b}{1+b}\sin(\zeta+\zeta'),$$

where

$$= \frac{2}{1+b}L\sec\mu\sin(\zeta'-\mu) + \frac{1-b}{1+b}\sin(\zeta+\zeta'),$$

in which $\tan\mu = \frac{M}{L}$, and μ represents the displacement of the line of no deviation towards the starboard side.

"By means of these equations we can determine A', L, b, M, c, N, from observations made at sea alone. The first four of these quantities furnish the corrections for the horizontal force and the declination. There is greater difficulty in obtaining the correction for the inclination. It will be observed that θ only occurs in these equations involved in the quantities L and N. If there were no permanent magnetism in the vessel, it would be necessary, in order to determine the correcting factors a and d, that observations of the inclination on shore, and corresponding observations on board, should be made in at least one magnetic latitude. If there is any appreciable permanent magnetism, observations of the inclination on shore and on board, and of the horizontal force, should be made in at least two magnetic latitudes. This would be sufficient if a, P, d, R remained absolutely constant. As that appears not to be

General Table of the Declinations observed on board Her Majesty's Ships Erebus and Terror, between May 1841 and August 1842.

Lat.	Long.	Ship.	No. of observations.	Declination.
° ′	° ′			° ′
−42 52	147 24	On shore at Hobarton.	....	−10 24
−43 30	147 20	Terror.	4	−12 35
−42 40	148 45	Erebus.	2	−10 06
−42 17	149 30	Terror.	5	−11 49
−40 40	149 23	Erebus.	2	− 9 51
−40 51	149 21	Terror.	5	−11 11
−37 48	150 21	Erebus.	10	−11 01
−37 54	150 20	Terror.	8	−10 38
−37 14	151 34	Erebus.	13	− 9 31
−37 10	151 32	Terror.	10	−11 32
−33 51	151 17	On shore at Sydney.	....	− 9 51
−33 56	151 00	Terror.	4	−11 18
−33 54	153 50	Erebus.	2	−10 07
−33 35	162 47	Terror.	10	−14 26
−33 33	162 01	Erebus.	8	−12 02
−33 41	166 26	Erebus.	8	−13 34
−33 48	166 29	Terror.	16	−13 40
−33 32	167 35	Erebus.	7	−13 27
−33 37	168 04	Terror.	12	−15 02
−33 42	169 44	Erebus.	11	−12 54
−34 15	172 33	Terror.	9	−13 45
−34 31	173 28	Erebus.	11	−13 56
−34 32	173 47	Terror.	5	−13 42
−35 16	174 00	On shore, Bay of Islands.	....	−13 36
−36 39	177 58	Erebus.	11	−14 24
−38 03	179 32	Terror.	10	−14 55
−38 02	179 51	Erebus.	13	−14 44
−39 29	182 42	Terror.	11	−16 55
−39 10	182 43	Erebus.	13	−14 43
−40 51	183 16	Erebus.	11	−12 57
−41 59	183 28	Terror.	19	−15 13
−42 02	183 31	Erebus.	11	−14 24
−46 09	183 59	Erebus.	13	−16 35
−47 05	184 30	Terror.	11	−15 17
−47 32	184 52	Erebus.	11	−15 45
−48 53	186 48	Erebus.	15	−16 23
−49 21	188 32	Terror.	7	−16 52
−49 28	189 00	Erebus.	8	−17 51
−49 57	191 10	Terror.	7	−16 36
−50 03	191 27	Erebus.	12	−18 23
−50 54	192 33	Erebus.	6	−18 18
−50 53	192 30	Terror.	8	−16 37
−51 39	194 53	Erebus.	18	−15 16
−51 50	195 06	Terror.	8	−15 14
−52 43	202 14	Erebus.	10	−13 58
−53 05	204 33	Terror.	11	−14 54
−53 10	205 28	Erebus.	12	−13 06
−54 54	209 24	Erebus.	8	−14 26
−56 20	211 40	Terror.	14	−15 14
−56 19	211 53	Erebus.	18	−14 47
−56 54	212 23	Erebus.	8	−13 32
−57 03	212 15	Terror.	10	−15 14
−57 16	212 45	Erebus.	13	−13 54
−58 21	213 00	Terror.	9	−17 34
−58 20	213 13	Erebus.	12	−14 37
−62 49	212 13	Erebus.	12	−20 14
−62 46	212 13	Terror.	15	−20 03
−63 19	210 22	Erebus.	6	−20 39
−63 23	210 05	On ice.	5	−19 59
−63 23	209 43	Erebus.	14	−20 44
−63 21	209 48	Terror.	17	−20 56
−64 29	206 55	Erebus.	11	−22 00
−64 48	206 10	Terror.	9	−22 55
−64 54	206 05	Erebus.	8	−22 51
−65 14	205 56	Erebus.	8	−21 51
−65 30	205 57	Erebus.	8	−22 46
−66 04	203 51	Erebus.	4	−24 13
−65 32	204 57	Terror.	7	−24 27
−66 22	203 40	Erebus.	11	−25 36
−66 04	203 16	Erebus.	8	−26 59
−66 10	203 37	Terror.	7	−27 24
−66 16	204 39	Erebus.	6	−26 36
−66 15	204 23	Erebus.	10	−25 55
−66 04	204 14	Erebus	16	−25 48
−66 02	204 00	Terror.	18	−26 48
−66 00	204 11	Erebus.	11	−25 26
−65 58	203 54	Terror.	11	−25 00
−65 57	204 14	Erebus.	13	−25 24
−65 58	203 54	Terror.	11	−25 59
−65 55	203 28	Erebus.	17	−24 58
−65 47	202 13	On ice.	6	−25 15
−65 59	203 07	Terror.	15	−26 24
−67 38	204 20	Erebus.	9	−27 46
−67 40	204 10	Terror.	9	−28 19
−67 20	202 02	Erebus.	8	−27 36
−67 19	202 35	Terror.	11	−28 37
−67 19	201 56	Erebus.	8	−28 12
−67 20	201 40	Terror.	11	−28 33
−68 32	200 07	Erebus.	14	−30 25
−68 24	199 57	Terror.	13	−32 43
−68 47	199 45	Erebus.	13	−32 33
−68 52	199 40	Terror.	7	−30 47
−70 10	186 15	Erebus.	9	−35 42
−70 25	185 38	Terror.	11	−38 55
−70 33	185 22	Erebus.	11	−38 21
−70 32	185 13	Terror.	12	−38 17
−70 23	184 31	Erebus.	10	−37 35
−70 14	184 00	Terror.	17	−37 19
−70 14	183 52	Erebus.	11	−36 28
−71 04	180 46	Terror.	5	−40 45
−72 10	180 58	Erebus.	1	−45 37
−73 14	181 08	Terror.	2	−51 48
−75 06	173 14	Erebus.	3	−77 17

General Table of the Inclinations observed on board Her Majesty's Ships Erebus and Terror, between May 1841 and August 1842.

Lat.	Long.	Ship.	No. of observations.	Inclination.	Lat.	Long.	Ship.	No. of observations.	Inclination.
° ′	° ′			° ′	° ′	° ′			° ′
−43 00	148 28	Erebus.	5	−70 25	−40 47	183 03	Erebus.	5	−62 21
−42 43	148 55	Terror.	8	−70 44	−40 42	183 05	Terror.	15	−61 56
−42 13	149 25	Erebus.	5	−69 37	−41 34	183 40	Terror.	7	−62 57
−40 51	149 28	Terror.	4	−69 05	−41 49	183 41	Erebus.	5	−63 28
−40 55	149 12	Erebus.	4	−68 41	−42 40	183 46	Terror.	7	−63 46
−38 17	150 22	Terror.	4	−66 57	−43 32	183 03	Erebus.	5	−64 44
−37 50	150 22	Erebus.	4	−66 36	−43 56	183 04	Terror.	15	−65 22
−37 28	151 30	Terror.	4	−66 22	−45 40	183 20	Erebus.	5	−66 35
−37 21	151 33	Erebus.	5	−66 01	−45 39	183 18	Terror.	14	−66 43
−36 21	151 39	Terror.	3	−66 11	−47 19	184 40	Erebus.	5	−67 56
−36 01	151 48	Erebus.	4	−65 04	−47 26	184 42	Terror.	14	−67 32
−34 06	151 19	Terror.	4	−62 58	−48 42	186 25	Terror.	15	−68 40
−33 51	151 20	Erebus.	19	−62 47	−48 43	186 30	Erebus.	6	−69 05
−33 51	151 17	Terror.	7	−62 59*	−49 24	187 23	Terror.	15	−68 59
−33 51	151 17	Erebus.	8	−62 48*	−49 23	188 29	Erebus.	9	−69 41
−33 51	151 17	Terror.	11	−62 52	−49 30	189 19	Terror.	14	−68 55
−33 51	151 17	Erebus.	7	−62 42	−50 03	191 20	Terror.	14	−68 43
−33 58	153 35	Terror.	8	−62 30	−50 24	191 40	Erebus.	10	−69 43
−33 52	154 07	Erebus.	5	−62 47	−50 38	192 05	Terror.	14	−69 25
−33 56	156 38	Terror.	4	−61 46	−51 48	194 25	Terror.	15	−69 51
−33 51	157 18	Erebus.	5	−62 07	−51 48	196 20	Erebus.	10	−70 21
−33 31	160 20	Terror.	4	−61 04	−52 28	199 05	Terror.	11	−70 10
−33 27	160 43	Erebus.	5	−61 30	−52 51	203 56	Terror.	8	−70 01
−33 42	164 05	Terror.	4	−60 52	−52 54	203 00	Erebus.	11	−70 44
−33 38	163 42	Erebus.	5	−60 48	−53 01	205 08	Erebus.	6	−70 10
−33 38	166 28	Erebus.	5	−60 07	−53 12	205 40	Terror.	15	−69 52
−33 44	166 37	Terror.	10	−59 55	−54 31	208 46	Terror.	11	−70 10
−33 33	167 38	Terror.	9	−59 58	−54 53	209 24	Terror.	12	−70 21
−33 22	167 40	Erebus.	5	−59 39	−55 01	209 47	Erebus.	10	−70 58
−33 00	169 00	Terror.	9	−58 43	−55 50	211 10	Erebus.	10	−71 28
−32 58	169 20	Erebus.	5	−59 04	−56 14	211 43	Terror.	14	−71 41
−32 12	170 27	Erebus.	4	−58 33	−56 39	212 10	Erebus.	10	−72 18
−32 11	171 01	Terror.	11	−57 28	−56 06	212 20	Erebus.	6	−72 08
−33 57	171 58	Erebus.	8	−58 24	−56 40	211 57	Terror.	12	−72 00
−33 55	171 59	Terror.	5	−58 24	−57 06	212 12	Terror.	12	−72 14
−34 29	173 36	Erebus.	6	−58 26	−57 57	213 02	Terror.	10	−73 09
−33 58	172 06	Terror.	7	−58 14	−58 38	213 10	Terror.	11	−73 45
−34 15	172 50	Terror.	10	−58 48	−58 39	213 17	Erebus.	11	−73 45
−34 24	173 43	Terror.	7	−59 00	−61 12	213 52	Terror.	14	−75 32
−35 16	174 00	Terror.	3	−59 36	−61 18	213 57	Erebus.	11	−75 32
−35 16	174 00	Erebus.	10	−59 31†‡	−62 36	212 36	Terror.	8	−76 37
−35 16	174 00	Terror.	14	−59 25‡	−62 40	212 53	Erebus.	7	−76 36
−35 16	174 23	Erebus.	10	−59 28	−63 11	210 18	Terror.	12	−77 37
−36 05	176 17	Terror.	12	−59 20	−63 23	210 02	Erebus.	5	−77 26
−36 27	177 34	Erebus.	5	−59 54	−63 23	210 02	Erebus.	4	−77 25§
−38 17	179 51	Erebus.	6	−60 34	−63 23	210 02	Erebus.	3	−77 30
−38 16	179 58	Terror.	15	−60 37	−63 36	208 20	Terror.	10	−77 53
−38 54	182 17	Terror.	17	−61 21	−63 49	208 29	Terror.	10	−77 56
−39 08	182 30	Erebus.	11	−61 34	−63 47	208 26	Erebus.	5	−77 57
−39 21	182 57	Terror.	16	−61 15	−64 25	206 29	Terror.	14	−78 30

* On shore at Garden Island, Sydney; inclination by needles whose poles were reversed, −62° 49′·1.

† Correct; in page 174 it is printed by mistake −59° 29′.

‡ On shore at the Bay of Islands, New Zealand; inclination by needles whose poles are reversed, −59° 31′·9.

§ On ice; the inclination observed with needles whose poles were reversed, was −77° 23′·3.

General Table of Inclination. (Continued.)

Lat.	Long.	Ship.	No. of observations.	Inclination.	Lat.	Long.	Ship.	No. of observations.	Inclination.
−60° 16′	211° 52′	Terror.	8	−74° 14′	−59° 00′	267° 18′	Erebus.	6	−67° 39′
−59 58	216 28	Terror.	7	−73 36	−59 02	271 58	Erebus.	5	−67 01
−59 24	218 55	Erebus.	11	−73 30	−59 01	272 06	Terror.	8	−66 53
−59 07	219 12	Terror.	17	−73 48	−58 54	276 18	Terror.	7	−66 10
−58 53	222 27	Erebus.	7	−73 38	−58 51	277 05	Erebus.	6	−65 27
−59 04	228 09	Terror.	9	−73 25	−58 25	279 44	Terror.	8	−64 44
−59 03	228 33	Erebus.	7	−72 57	−58 23	280 03	Erebus.	5	−64 49
−59 39	232 48	Erebus.	5	−72 54	−58 31	281 38	Terror.	9	−63 48
−59 45	233 55	Erebus.	4	−72 51	−58 29	282 10	Erebus.	5	−63 41
−60 09	236 11	Terror.	11	−73 01	−58 36	285 33	Terror.	7	−63 00
−60 16	236 11	Erebus.	5	−73 00	−58 31	285 56	Erebus.	5	−63 05
−60 21	237 02	Erebus.	5	−72 45	−57 21	289 36	Terror.	7	−61 36
−60 22	237 14	Terror.	10	−73 08	−57 22	289 50	Erebus.	5	−61 15
−60 20	237 54	Erebus.	9	−72 44	−57 26	291 36	Terror.	8	−59 52
−60 01	241 31	Erebus.	5	−72 40	−57 11	292 14	Erebus.	6	−58 51
−59 17	245 40	Erebus.	5	−71 29	−56 37	294 34	Terror.	7	−59 02
−59 11	246 37	Terror.	10	−71 24	−56 40	294 46	Erebus.	5	−59 01
−59 15	248 12	Erebus.	5	−71 26	−54 48	297 21	Terror.	7	−56 48
−58 59	249 18	Erebus.	6	−71 04	−54 50	298 08	Erebus.	4	−56 10
−58 26	251 42	Terror.	7	−70 55	−52 54	300 27	Erebus.	5	−53 52
−58 29	252 18	Erebus.	5	−70 50	−52 34	300 10	Terror.	15	−53 25
−58 33	254 45	Terror.	7	−70 16	−52 03	301 56	Erebus.	3	−52 34
−58 35	255 10	Erebus.	5	−70 11	−51 42	301 36	Terror.	7	−52 04
−58 42	257 44	Terror.	10	−69 50	−51 32	301 53	Erebus.	8	−52 36*
−58 45	257 58	Erebus.	5	−69 47	−51 32	301 53	Terror.	25	−52 15*
−58 58	267 18	Terror.	8	−68 00					

* Observed on shore at the Falkland Islands; the Inclination with needles whose poles were reversed, was 52^c 26′2.

General Table of the Intensity of the Magnetic Force. (Continued.)

Lat.	Long.	Ship.	No. of observations.	Intensity. London = 1·372.	Lat.	Long.	Ship.	No. of observations.	Intensity. London = 1·372.
−66° 03′	202° 29′	Terror.	12	1·945	−67° 35′	185° 18′	Terror.	10	1·978
−65 49	202 02	Erebus.	6	1·959 *	−67 24	187 51	Terror.	8	1·981
−65 47	202 08	Terror.	10	1·948 *	−66 56	189 36	Erebus.	4	1·980
−67 16	203 40	Erebus.	8	1·976	−65 17	191 58	Terror.	10	1·955
−67 46	204 17	Terror.	10	1·960	−63 30	194 15	Terror.	4	1·942
−67 37	204 12	Terror.	10	1·965	−63 05	195 18	Erebus.	6	1·941
−67 21	202 15	Erebus.	6	1·967	−61 57	196 33	Terror.	14	1·916
−67 12	202 24	Terror.	6	1·946	−61 07	199 05	Erebus.	7	1·924
−67 15	201 34	Terror.	8	1·935	−60 19	203 42	Terror.	4	1·920
−68 08	199 57	Terror.	8	1·955	−60 16	207 52	Erebus.	4	1·881
−68 29	199 55	Erebus.	9	1·991	−60 15	209 55	Terror.	8	1·907
−68 46	199 39	Terror.	13	1·961	−59 13	216 28	Terror.	4	1·910
−68 52	198 24	Terror.	10	1·966	−59 22	218 14	Terror.	4	1·900
−69 29	192 24	Erebus.	8	2·001	−58 33	220 27	Erebus.	7	1·878
−70 00	191 36	Terror.	9	1·965	−58 49	221 25	Terror.	4	1·913
−70 14	196 16	Terror.	15	1·976	−59 01	227 43	Terror.	4	1·897
−70 18	185 16	Terror.	10	1·983	−59 29	231 53	Erebus.	6	1·890
−70 23	185 33	Erebus.	8	1·996	−60 18	236 31	Erebus.	6	1·909
−70 27	181 59	Terror.	8	1·988	−60 05	235 56	Terror.	4	1·884
−70 28	181 20	Erebus.	5	1·999	−60 17	236 38	Terror.	4	1·892
−72 41	181 41	Terror.	8	2·001	−60 20	237 55	Erebus.	4	1·907
−72 46	181 46	Erebus.	4	1·989	−60 24	237 29	Terror.	4	1·907
−74 58	173 34	Terror.	10	2·008	−59 05	247 27	Terror.	4	1·875
−75 05	173 17	Erebus.	9	2·024	−59 31	245 13	Erebus.	8	1·861
−75 42	174 14	Terror.	7	2·006	−58 26	251 42	Terror.	4	1·885
−76 33	180 09	Erebus.	6	2·021	−58 33	254 45	Terror.	10	1·824
−77 02	181 37	Terror.	4	2·007	−58 36	255 30	Erebus.	7	1·821
−76 48	184 46	Terror.	4	2·009	−58 47	258 13	Terror.	8	1·832
−76 20	191 26	Terror.	4	2·024	−58 59	267 50	Terror.	4	1·783
−76 24	184 54	Terror.	4	2·004	−59 01	272 06	Terror.	4	1·747
−77 00	194 38	Erebus.	8	2·009	−58 58	272 35	Erebus.	6	1·747
−77 13	193 52	Terror.	10	2·011	−58 24	276 18	Terror.	4	1·722
−77 47	197 25	Terror.	4	2·001	−58 27	280 20	Terror.	12	1·672
−77 14	199 29	Terror.	10	1·992	−58 27	282 04	Erebus.	5	1·652
−75 20	194 36	Terror.	4	2·003	−58 36	285 33	Terror.	4	1·648
−74 50	193 45	Erebus.	2	1·999	−57 23	290 34	Terror.	8	1·592
−73 10	189 21	Terror.	4	2·000	−57 16	292 01	Erebus.	5	1·544
−72 24	188 47	Erebus.	4	1·990	−55 42	295 57	Terror.	8	1·495
−72 03	187 40	Terror.	10	1·999	−56 03	295 54	Erebus.	3	1·478
−71 34	186 09	Terror.	10	1·999	−52 40	299 52	Terror.	9	1·355
−71 08	184 59	Erebus.	4	2·009	−52 54	300 57	Erebus.	5	1·367
−69 54	179 55	Terror.	4	1·999	−52 05	301 39	Terror.	8	1·340
−69 48	179 56	Erebus.	4	1·994	−51 32	301 53	Erebus.	24	1·333†
−68 09	183 10	Terror.	4	1·981	−51 32	301 53	Terror.	30	1·336†
−68 04	183 25	Erebus.	4	1·981					

* Observed on ice,

† On shore at the Falkland Islands.

Declinations observed on board Her Majesty's Ship Erebus, between June 1841 and August 1842.

The Observers are distinguished in the column of Initials as follows:—R. Captain Ross; S. Lieut. Sibbald; W. Lieut. Wood; T. Mr. Tucker, Master; Sm. Mr. Smith, and O. Mr. Oakley, Mates; Y. Mr. Yule, Second Master. East Declination is characterised by the sign —.

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
May 10	−42° 52′	147° 24′	R.	−10° 24′·5	Mean, 7 days' hourly observations with Declin. No. 1.					−10° 24′	At the Magnetic Observatory.
19	Hobarton, Van Diemen Island.		R.	−10 24·3	Mean, 7 days' hourly observations with Declin. No. 2.						
			R.	−10 36	N.	To obtain corrections for the ship's attraction.					
			R.	−11 24	N. by W.						
			R.	−12 11	N.N.W.						
			R.	−12 44	N. W. by N.						
			R.	−13 04	N.W.						
			R.	−13 22	N.W. by W.						
			R.	−14 01	W.N.W.						
			R.	−14 42	W. by N.						
			R.	−15 08	W.						
			R.	−15 06	W. by S.						
			R.	−14 51	W.S.W.						
			R.	−14 29	S.W. by W.						
			R.	−13 51	S.W.						
			R.	−13 08	S.W. by S.						
			R.	−12 25	S.S.W.						
			R.	−10 29	S. by W.						
June 29	At anchor.		R.	− 9 26	S.						
			R.	− 7 38	S. by E.						
			R.	− 7 03	S.S.E.						
			R.	− 6 19	S.E. by S.						
			R.	− 5 36	S.E.						
			R.	− 5 09	S.E. by E.						
			R.	− 4 24	E.S.E.						
			R.	− 4 49	E. by S.						
			R.	− 5 02	E.						
			R.	− 5 24	E. by N.						
			R.	− 6 04	E.N.E.						
			R.	− 6 24	N.E. by E.						
			R.	− 7 01	N.E.						
			R.	− 7 30	N.E. by N.						
			R.	− 8 40	N.N.E.						
			R.	− 9 32	N. by E.						
July 7 P.M.	−43 17	148 07	R.	− 5 33	E.S.E.	−70 50	−4 44	−10 17	−0 37	−10 06	
9 P.M.	−42 04	149 24	T.	−12 30	W.N.W.	−69 40	+3 49	− 8 41			
10 A.M.	−40 55	149 12	T.	−10 15	N. by W.	−68 40	+0 39	− 9 36	−0 37	− 9 51	
10 P.M.	−40 26	149 34	T.	− 8 52	N.		0 00	− 8 52			
11 P.M.	−37 49	150 21	R.	−10 47	N.	−66 40	0 00	−10 47	−0 37	−11 01	
			R.	− 9 57	N.		0 00	− 9 57			
			T.	−10 56	N. by W.		+0 35	−10 21			
			T.	−10 55	N. by W.		+0 35	−10 20			
			R.	−10 54	N. by W.		+0 35	−10 19			
			R.	−10 04	N.		0 00	−10 04			
			R.	−11 44	N.N.W.		+1 10	−10 34			
			S.	−11 53	N. by W.		+0 35	−11 18			
			T.	−11 17	N. by W.		+0 35	−10 42			
	−37 43	150 22	R.	−10 18	N. by W.		+0 35	− 9 43			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
July 12 A.M.	−37° 24′	151° 27′	R.	− 6° 30′	N.E.	−66° 00′	−2° 10′	− 8° 40′	−0° 37′	− 9° 31′	
			R.	− 6 11	N.E.		−2 10	− 8 21			
			R.	− 5 39	N.E.		−2 10	− 7 49			
	−37 22	151 28	W.	− 7 53	N.N.E.		−1 07	− 9 00			
12 P.M.	−37 17	151 39	S.	− 6 06	N.E. ¾ E.		−2 34	− 8 40			
			S.	− 6 37	N.E.		−2 10	− 8 47			
	−37 16	151 37	Y.	− 9 36	N. by W.		+0 34	− 9 02			
			R.	− 8 34	N. by W.		+0 34	− 8 00			
			S.	− 9 33	N. by W.		+0 34	− 8 59			
			S.	− 9 45	N. by W.		+0 34	− 9 11			
			R.	− 9 29	N. by W.		+0 34	− 8 55			
	−37 11	151 37	T.	− 9 09	N.		0 00	− 9 09			
13 A.M.	−36 26	151 42	T.	−12 04	N.N.W.	−65 00	+1 03	−11 01			
Aug. 3	Garden Island, Sydney.		R.	− 9 51·5	....	....	....	......	....	− 9 51·5	By the magnetometers on shore.
	−33 51	151 17									
6 A.M.	−33 54	153 50	S.	− 7 05	E.	−62 40	−3 13	−10 18	−0 37	−10 07	
			T.	− 5 42	E. by N.		−3 00	− 8 42			
8 P.M.	−33 30	160 56	S.	− 7 47	E. by N.	−61 30	−2 50	−10 37	−0 37	−12 02	
			S.	− 7 58	E.		−3 03	−11 01			
			O.	− 7 54	E. by N.		−2 50	−10 44			
			R.	− 8 21	E.		−3 03	−11 24			
			R.	− 6 30	E.		−3 03	− 9 33			
9 A.M.	−33 38	163 50	T.	−10 37	E.	−60 40	−2 56	−13 13			
			R.	− 9 45	E.		−2 56	−12 41			
			T.	− 9 23	E.		−2 56	−12 19			
10 A.M.	−33 42	166 25	R.	−12 53	N.N.E.	−60 10	−0 48	−13 41	−0 37	−13 34	
			T.	−10 59	S.E. by E.		−2 50	−13 49			
			S.	− 9 55	E.		−2 52	−12 47			
			T.	− 9 28	E. by S.		−2 59	−12 27			
			W.	−11 20	E.S.E.		−2 59	−14 19			
	−33 41	166 19	Sm.	− 8 55	E.		−2 52	−11 47			
10 P.M.	−33 39	166 34	O.	− 8 35	E. by N.		−2 39	−11 14			
			T.	−10 50	E. by N.		−2 39	−13 29			
11 A.M.	−33 32	167 34	R.	−11 56	N.E. by N.	−59 40	−1 10	−13 06	−0 37	−13 27	
			T.	−10 46	E.S.E.		−2 56	−13 42			
			W.	−10 32	E. ½ N.		−2 42	−13 14			
			O.	−10 51	E.S.E.		−2 56	−13 47			
			Sm.	− 7 46	E. by S.		−2 56	−10 42			
			T.	−10 32	E.		−2 49	−13 21			
	−33 32	167 41	S.	− 9 03	E. by S.		−2 56	−11 59			
11 P.M.	−33 31	167 51	S.	−11 11	E.N.E.	−59 30	−2 16	−13 27	−0 37	−12 54	
			R.	−11 04	E.N.E.		−2 16	−13 20			
			R.	−11 13	E.		−2 48	−14 01			
			O.	−10 48	E. by N.		−2 42	−13 30			
			S.	− 9 45	E. by N.		−2 42	−12 27			
	−33 32	167 59	R.	−10 29	E. by N.		−2 42	−13 11			
15 A.M.	−33 55	171 58	T.	− 8 13	E. by S.	−58 10	−2 47	−11 00			
			O.	− 8 02	E. ½ S.		−2 44	−10 46			
			S.	− 8 33	E. ½ S.		−2 44	−11 17			
			T.	− 8 15	E. by S.		−2 47	−11 02			
	−33 54	171 58	R.	− 8 22	E. by S. ½ S.		−2 47	−11 09			
16 A.M.	−34 25	172 51	Y.	−14 11	N.N.W. ½ W.	−58 10	+0 53	−13 18	−0 37	−13 56	
			Y.	−13 09	N.W. ½ W.		+1 38	−11 31			
			Y.	−14 46	N.W. by N.		+1 04	−13 42			
			T.	−14 58	N.W. ½ N.		+1 14	−13 44			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
Aug. 17 A.M.	−34° 15′	173° 12′	T.	−11° 14′	E. by S.	−58° 10′	−2° 48′	−14° 02′	−0° 37′	−13° 56′	
17 P.M.	−34 37	173 55	S.	−10 11	E.S.E.		−2 48	−12 59			
			O.	−11 20	E.S.E.		−2 48	−14 08			
			R.	−10 18	E.S.E.		−2 48	−13 06			
			R.	−10 39	E. by S. ½ S.		−2 48	−13 27			
			O.	− 9 25	E. by S. ½ S.		−2 48	−12 13			
			R.	−11 27	E. by S.		−2 48	−14 15			
Aug. & Sept.	Bay of Islands.										
	−35 16	174 00	R.	−13 36	....	....	....	......	....	−13 36	By the magnetometers on shore.
Nov. 24 A.M.	−36 27	177 20	SM.	− 8 57	E.S.E.	−59 40	−2 45	−11 42	−1 20	−14 24	
		177 21	O.	− 8 51	E.S.E.		−2 45	−11 36			
24 P.M.	−36 34	177 47	S.	−10 45	S.E. by E.		−2 36	−13 21			
		177 56	S.	−11 46	S.E. by E.		−2 36	−14 22			
	−36 40	177 58	O.	−11 52	S.E. by E.		−2 36	−14 28			
	−36 42	178 08	R.	− 9 47	S.E. by E.		−2 36	−12 23			
	−36 44	178 10	R.	−10 38	S.E. by E.		−2 36	−13 14			
			T.	−10 19	S.E. by E.		−2 36	−12 55			
			T.	−11 20	S.E. by E.		−2 36	−13 56			
	−36 50	178 18	R.	−10 13	S.E. by E.		−2 36	−12 49			
			R.	−10 27	S.E. by E.		−2 36	−13 03			
25 A.M.	−37 59	179 37	T.	−11 54	S.E. by S.	−60 14	−1 56	−13 50	−1 20	−14 44	
			SM.	−11 11	S.E. by S.		−1 56	−13 07			
	−38 01	179 40	T.	−11 07	S.E. ½ S.		−2 09	−13 16			
			SM.	−10 29	S.E. by S.		−1 56	−12 25			
			O.	−11 42	S.E. ½ S.		−2 09	−13 51			
			S.	−10 06	S.E.		−2 22	−12 28			
	−38 03	179 41	T.	−11 15	S.E. ½ S.		−2 09	−13 24			
25 P.M.	−38 22	180 10	R.	−10 43	E.S.E.	−60 20	−2 49	−13 32			
			Y.	−10 19	S.E. ½ E.		−2 32	−12 51			
	−38 27	180 02	R.	−11 09	S.E. ½ E.		−2 32	−13 41			
			R.	−11 26	S.E. by E.		−2 40	−14 06			
			T.	−10 06	S.E. by E. ½ E.		−2 44	−12 50			
			R.	−11 39	S.E. by E.		−2 40	−14 17			
26 P.M.	−39 04	182 29	O.	−11 29	S.E. by E.	−61 05	−2 44	−14 13	−1 20	−14 43	
			T.	−10 10	S.E. ½ E.		−2 35	−12 45			
			T.	−11 05	S.E. by E.		−2 44	−13 49			
	−39 05	182 32	R.	−10 37	S.E. by E. ½ E.		−2 49	−13 26			
			R.	− 9 39	E.S.E.		−2 53	−12 32			
			R.	−10 36	S.E. by E.		−2 44	−13 20			
	−39 08	182 36	T.	− 9 49	S.E. by E.		−2 44	−12 33			
	−39 09	182 40	R.	− 9 49	E.S.E.		−2 53	−12 42			
27 A.M.	−39 16	182 59	T.	−11 47	N.E. by E.	−61 42	−1 58	−13 45			
			SM.	−11 09	S.E. by E.		−2 48	−13 57			
			S.	−12 33	N.		0 00	−12 33			
			T.	−12 30	N.N.E. ¼ E.		−0 53	−13 23			
	−39 17	182 58	O.	−12 41	N.N.E. ½ E.		−0 58	−13 39			
28 A.M.	−40 23	183 04	S.	−12 02	S. by E.	−62 12	−0 45	−12 47	−1 20	−12 57	
	−40 27	183 03	T.	−11 20	S. by E.		−0 45	−12 05			
28 P.M.	−40 22	183 14	R.	− 9 10	S.S.E. ½ E.		−1 46	−10 56			
	−40 57		T.	− 9 32	S.S.E.		−1 27	−10 59			
		183 16	R.	− 8 46	S.E. by S.		−2 04	−10 50			
			O.	− 8 53	S.E. ½ S.		−2 17	−11 10			
	−41 07	183 22	R.	− 9 34	S.E.		−2 31	−12 05			
			S.	−10 10	S.E.		−2 31	−12 41			
	−41 09	183 23	R.	−10 33	S.S.E.		−1 26	−11 59			
	−41 10	183 24	R.	− 9 12	S.E. by S.		−2 03	−11 15			
	−41 11	183 25	R.	− 8 56	S.E. by S.		−2 03	−10 59			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Nov. 29 A.M.	−41 28	183 41	Y.	−15 20	W.S.W.	−63 20	+3 09	−12 11	−1 20	−14 24	
			T.	−14 41	S.W. ½ S.		+2 23	−12 18			
			T.	−11 59	S. by E.		−0 47	−12 46			
			T.	−12 55	S. by E.		−0 47	−13 42			
	−41 30	183 43	T.	−13 02	S. by E.		−0 47	−13 49			
			S.	−10 38	S. by E.		−0 47	−11 25			
			T.	−12 15	S. by E.		−0 47	−13 02			
	−41 31	183 40	O.	−13 14	S. by E.		−0 47	−14 01			
30 A.M.	−43 28	183 04	R.	−13 23	S. ¼ E.	−65 00	−0 16	−13 39			
			T.	−14 02	S.		0 0	−14 02			
	−43 30	183 03	O.	−12 49	S.		0 0	−12 49			
Dec. 1 A.M.	−45 30	183 15	T.	−12 16	S.E. by E. ½ E.	−66 30	−3 24	−15 40	−1 20	−16 35	
			W.	−11 47	S.E. by E.		−3 18	−15 05			
			Y.	−13 08	S.E. by E.		−3 18	−16 26			
	−45 32	183 11	T.	−11 02	S.E. by E. ½ E.		−3 24	−14 26			
			W.	−10 22	S.E. by E.		−3 18	−13 40			
		183 15	S.	−12 26	S.E. by E.		−3 18	−15 44			
2 A.M.	−46 40	184 18	T.	−12 30	S.E. by E. ½ E.	−67 55	−3 44	−16 14			
			W.	−11 54	S.E. by E.		−3 36	−15 30			
			Y.	−10 33	S.E. by E.		−3 36	−14 09			
			Sm.	−11 24	S.E. by E.		−3 36	−15 00			
			T.	−12 31	S.E. by E. ½ E.		−3 44	−16 15			
			T.	−11 33	E.S.E.		−3 52	−15 25			
	−46 45	183 13	Sm.	−11 07	S.E. by E.		−3 36	−14 43			
2 P.M.	−47 26	184 42	S.	−11 28	E. by S.	−67 55	−3 57	−15 25	−1 20	−15 45	
	−47 31	184 50	T.	−11 00	S.E. ½ E.		−3 24	−14 24			
			T.	−11 29	S.E. by E. ½ E.		−3 44	−15 13			
	−47 32	184 53	T.	−10 36	S.E. by E.		−3 36	−14 12			
			W.	−11 28	S.E. ½ E.		−3 24	−14 52			
			S.	−11 32	S.E. by E.		−3 36	−15 08			
			T.	−10 43	S.E. by E.		−3 36	−14 19			
			O.	−11 07	S.E. ½ E.		−3 24	−14 31			
	−47 34	184 55	R.	−10 27	S.E. ¾ E.		−3 30	−13 57			
			R.	− 9 25	S.E. by E.		−3 36	−13 01			
	−47 38	185 00	R.	− 9 47	S.E. by E. ½ E.		−3 44	−13 31			
3 P.M.	−48 50	186 47	S.	−12 19	N.E. by E. ½ E.	−69 05	−3 11	−15 30	−1 20	−16 23	
			S.	−11 26	E.S.E.		−4 04	−15 30			
			T.	−11 35	E. ½ N.		−3 52	−15 27			
	−48 53	186 49	R.	−10 25	S.E. by E.		−3 47	−14 12			
			R.	−11 01	S.E. by E.		−3 47	−14 48			
			O.	−10 53	S.E. by E. ½ E.		−3 55	−14 48			
			Sm.	−11 32	S.E. by E.		−3 47	−15 19			
	−48 50	186 44	Y.	−10 48	S.E. by E. ½ E.		−3 55	−14 43			
			T.	−10 49	S.E. by E.		−3 47	−14 36			
	−48 51	186 44	W.	−10 59	S.E. by E.		−3 47	−14 46			
			S.	−11 20	S.E. by E.		−3 47	−15 07			
			R.	−10 23	E.S.E.		−4 04	−14 27			
	−48 54	186 46	T.	−10 49	E.S.E.		−4 04	−14 53			
	−48 55	186 52	R.	−11 42	S.E. by E.		−3 47	−15 29			
	−48 56	186 53	R.	−12 35	S.E. ½ E.		−3 33	−16 08			
4 A.M.	−49 10	187 32	R.	−12 52	E. by S.	−69 40	−4 18	−17 10	−1 20	−17 51	
5 A.M.	−49 32	188 59	T.	−11 28	E. by S.		−4 18	−15 46			
			O.	−11 12	E. by S.		−4 18	−15 30			
			S.	−13 13	E. by S.		−4 18	−17 31			
5 P.M.	−49 31	189 20	S.	−13 21	E. by S.		−4 18	−17 39			
			W.	−11 45	E. by S.		−4 18	−16 03			
			T.	−12 35	E. by S.		−4 18	−16 53			
	−49 32	189 28	R.	−11 28	E.		−4 07	−15 35			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Dec. 13 A.M.	−54 45	209 02	S.	− 7 35	E.S.E.	−70 47	−4 27	−12 02	−1 20	−14 26	
			T.	− 7 51	S.E. by E. ½ E.		−4 17	−12 08			
	−54 46	209 07	R.	− 7 18	S.E. by E. ½ E.		−4 17	−11 35			
			T.	− 7 06	S.E. by E. ½ E.		−4 17	−11 23			
	−54 48	209 10	W.	− 7 40	S.E. by E.		−4 07	−11 47			
			R.	−10 24	S.E. by E. ½ E.		−4 17	−14 41			
13 P.M.	−55 16	210 14	S.	−11 36	S.E. by E.		−4 07	−15 43			
	−55 17	210 20	S.	−11 20	S.E. by E.		−4 07	−15 27			
14 A.M.	−56 06	211 33	T.	−12 31	S.E. by S.	−72 00	−3 03	−15 34	−1 20	−15 43	
	−56 04		Y.	−12 14	S.E. by S.		−3 03	−15 17			
	−56 10	211 44	T.	−11 45	S.E. by S.		−3 03	−14 48			
			Sm.	−12 52	S.E. by S.		−3 03	−15 55			
	−56 15	211 49	R.	−11 57	S.E. by S.		−3 03	−15 00			
14 P.M.	−56 22	211 56	T.	− 8 36	E. ¼ N.		−4 35	−13 11			
			S.	− 9 02	E.N.E.		−4 02	−13 04			
			T.	− 9 44	E.N.E.		−4 02	−13 46			
			T.	−10 01	N.E.		−2 54	−12 55			
			S.	− 9 03	N.E. ½ E.	−72 00	−3 13	−12 16	−1 20	−13 50	
			S.	− 8 11	E. ½ N.		−4 35	−12 46			
		211 58	R.	− 8 51	E.N.E.		−4 02	−12 53			
			W.	− 8 51	E. by N.		−4 27	−13 18			
	−56 23	211 59	R.	− 8 37	S.E. by S.		−3 03	−11 40			
			T.	− 9 10	S.E. by S.		−3 03	−12 13			
			W.	− 9 02	S.E. by S.		−3 03	−12 05			
			T.	− 9 31	S.E. by S.		−3 03	−12 34			
	−56 24	211 59	W.	− 9 44	S.E. by S.		−3 03	−12 47			
15 A.M.	−56 50	212 12	T.	−11 01	S. by E. ½ E.	−72 39	−1 40	−12 41	−1 20	−13 32	
			Sm.	−11 34	S. by E.		−1 08	−12 42			
			Y.	−10 29	S.S.E.		−2 13	−12 42			
			T.	−10 25	S.S.E.		−2 13	−12 38			
			S.	− 9 31	S.S.E.		−2 13	−11 44			
	−56 59	212 41	O.	− 9 21	S.E. by S.		−3 09	−12 30			
			R.	− 8 24	S.E. by S.		−3 09	−11 33			
	−57 01	212 42	R.	− 7 56	S.E. by S.		−3 09	−11 05			
15 P.M.	−57 13	212 45	T.	− 9 41	S.S.E.	−72 12	−2 10	−11 51	−1 20	−13 54	
			S.	− 9 43	S.S.E.		−2 10	−11 53			
			W.	− 9 36	S.S.E.		−2 10	−11 46			
			R.	− 9 45	S.S.E.		−2 10	−11 55			
	−57 14	212 45	T.	− 9 28	S.S.E.		−2 10	−11 38			
			R.	− 9 51	S.S.E.		−2 10	−12 01			
			Y.	−11 51	S.S.E.		−2 10	−14 01			
	−57 16	212 45	T.	−10 12	S.S.E.		−2 10	−12 22			
			T.	− 9 11	E.N.E.		−4 05	−13 16			
			S.	− 8 07	E.N.E.		−4 05	−12 12			
			S.	− 9 29	E.S.E.		−4 47	−14 16			
			S.	− 8 53	S.E.		−3 51	−12 44			
	−57 19	212 47	R.	−11 12	S.S.E.		−2 10	−13 22			
16 A.M.	−58 12	213 09	S.	− 9 20	S.S.E.	−73 55	−2 21	−13 12	−1 20	−14 37	
	−58 13	213 08	T	− 9 27	S.S.E.						
			O.	− 9 44	S.S.E.						
			S.	−10 37	S.S.E.						
	−58 15	213 08	T.	−10 08	S.S.E.						
			Y.	−10 47	S.S.E.						
			T.	−11 56	S.S.E.						
	−58 21	213 17	R.	−12 32	S.S.E.						
			W.	−11 17	S.S.E.						
			R.	−12 08	S.S.E.						
	−58 25	213 06	R.	−11 28	S.S.E.						
17 A.M.	−60 02	213 45	S.	−11 32	S.S.E.	−75 40	−2 40	−14 12			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Dec. 18 A.M.	−62 40	212 49	T.	−17 18	S. ½ E.	−76 49	−0 44	−18 02	−1 20	−20 14	
			R.	−19 25	S. by W.		+1 28	−17 57			
			W.	−19 14	S. ¼ W.		+0 22	−18 52			
	−62 45	212 44	R.	−20 47	S. by W.		+1 28	−19 19			
			Sm.	−19 54	S. ½ W.		+0 44	−19 10			
18 P.M.	−62 50	211 46	R.	−26 11	S.W. ½ W.		+5 30	−20 41			
	−62 53	211 34	R.	−25 40	S.W. ½ W.		+5 30	−19 10			
	−62 56	211 20	R.	−23 59	S.W. ½ W.		+5 30	−18 29			
			T.	−23 47	S W. ½ W.		+5 30	−18 17			
			W.	−25 11	S.W. ¾ W.		+5 41	−19 30			
			R.	−21 25	S.S.W.		+2 57	−18 28			
	−62 57	211 20	R.	−21 49	S.S.W.		+2 57	−18 52			
19 A.M.	−63 19	210 25	S.	−23 12	S.W.	−77 40	+5 27	−17 45	−1 20	−20 39	
	−63 20	210 22	O.	−23 26	S.S.W. ½ W.		+3 45	−19 41			
			W.	−23 32	S.S.W. ½ W.		+3 45	−19 47			
			T.	−23 34	S.W. by S.		+4 25	−19 09			
			T.	−22 11	S.S.W.		+3 11	−19 00			
	−63 19	210 17	R.	−22 07	S. by W.		+1 33	−20 34			
	−63 23	210 05	R.	−19 19	Observed on ice.	−77 36	......	−19 19	−0 06	−19 59	H 162
			R.	−20 43				−20 43	−0 28		H 167
			R.	−22 35				−22 35	+1 00		H 166
			R.	−18 24				−18 24	−0 06		H 162
			R.	−18 44				−18 44	−0 28		H 167
19 P.M.	−63 23	210 05	S.	−13 00	E.N.E.	−77 36	−6 07	−19 07	−1 20	−20 44	
			T.	−13 39	E. by N.		−6 40	−20 19			
			T.	−26 28	W.S.W.		+6 46	−19 42			
			T.	−21 32	S. by W. ¾ W.		+2 44	−18 48			
			S.	−23 31	S.S.W. ¼ W.		+3 27	−20 04			
			T.	−23 58	S. 42° W.		+5 10	−18 48			
			S.	−24 37	S.W.		+5 25	−19 12			
			S.	−26 46	S.W. by W. ½ W.		+6 22	−20 24			
			T.	−21 44	S. 22° W.		+3 07	−18 37			
			T.	−24 23	S. 42° W.		+5 10	−19 13			
			T.	−23 43	S. 33° W.		+4 18	−19 25			
			S.	−23 21	S.W. by S.		+4 21	−19 00			
			T.	−25 01	S. 54° W.		+6 20	−18 41			
	−63 24	209 39	T.	−27 10	W.S.W.		+6 47	−20 23			
20 A.M.	−63 36	208 45	S.	−23 40	S.W. by S.	−78 30	+4 39	−19 01	−1 20	−22 00	
			O.	−23 49	S.S.W.		+3 17	−20 32			
	−63 52	208 00	T.	−23 16	S. by W. ½ W.		+2 29	−20 47			
21 A.M.	−64 39	206 55	T.	−19 00	S. ½ E.		−0 50	−19 50			
	−64 48	206 18	S.	−18 26	S.S.E.		−3 17	−21 43			
			T.	−18 31	S. by E.		−1 40	−20 11			
			W.	−18 08	S. by E. ½ E.		−2 29	−20 37			
			T.	−20 30	S.		0 0	−20 30			
			S.	−21 18	S.		0 0	−21 18			
	−64 49	206 10	R.	−25 18	S.W. by S.		+4 39	−20 39			
	−64 50	206 05	W.	−20 29	S. by E.		−1 40	−22 09			
			T.	−19 35	S. ½ E.	−78 50	−0 51	−20 26	−1 20	−22 51	
			R.	−21 56	S. ¾ W.		+1 16	−20 40			
	−64 54	206 06	R.	−19 25	S. ¾ E.		−1 16	−20 41			
	−64 56	206 04	R.	−18 54	S. by E.		−1 40	−20 34			
			R.	−22 38	S. 11° E.		−1 36	−24 14			
			R.	−20 24	S. 9° E.		−1 18	−21 42			
			R.	−17 56	S. 8° E.		−1 09	−19 05			
			R.	−23 07	S. 11° E.		−1 36	−24 43			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Dec. 22 A.M.	−65 14	206 07	S.	−22 02	s. ¾ w.	−79 20	+1 20	−20 42	−1 20	−21 51	
			O.	−24 24	s. by w. ½ w.		+2 38	−21 46			
	−65 13	205 55	T.	−22 14	s. by w.		+1 47	−20 27			
			S.	−22 39	s. by w.		+1 47	−20 52			
	−65 13	205 47	Y.	−22 02	s. by w.		+1 47	−20 15			
			O.	−20 44	s. by w.		+1 47	−18 57			
			T.	−22 13	s. by w.		+1 47	−20 26			
			T.	−22 58	s. by w. ¼ w.		+2 14	−20 44			
	−65 16	206 00	W.	−23 00	s.s.w.	−79 20	+3 28	−19 32	−1 20	−22 46	
			W.	−19 56	s.		0 0	−19 56			
	−65 21	206 08	R.	−22 43	s. ½ w.		+0 53	−21 50			
	−65 23	206 06	R.	−23 11	s. ½ w.		+0 53	−22 18			
22 P.M.		205 50	S.	−18 11	s.s.e.		−3 28	−21 39			
	−65 38	205 47	T.	−21 14	s. ½ w.		+0 26	−20 48			
	−65 39	205 44	Y.	−22 02	s.		0 0	−22 02			
	−66 00	205 46	R.	−21 18	n. by e. ½ e.		−2 06	−23 24			
24 P.M.	−65 59	203 47	T.	−27 28	s.s.w.	−79 45	+3 35	−23 53	−1 20	−24 13	
25 P.M.	−66 01	203 56	T.	−26 45	n.w. by n.		+4 20	−22 25			
			T.	−14 34	s.e. by e. ½ e.		−7 50	−22 24			
27 A.M.	−66 16	203 44	S.	−14 42	e.s.e.		−8 10	−22 52			
28 A.M.	−66 17	203 36	S.	−16 17	e. by n. ½ n.	−80 00	−8 02	−24 19	−1 20	−25 36	
			T.	−30 17	s.w. by s.		+5 17	−25 00			
			T.	−29 00	s.s.w. ½ w.		+4 28	−24 32			
			R.	−30 56	s.w.		+6 39	−24 17			
			W.	−30 50	s.w.		+6 39	−24 11			
29 A.M.	−66 24	203 51	W.	−31 36	w.n.w.		+7 43	−23 53			
			T.	−31 41	w.n.w.		+7 43	−23 58			
			T.	−30 30	n.w. ½ w.		+6 18	−24 12			
29 P.M.	−66 25	203 51	S.	−17 13	e. by n. ½ n.		+8 02	−25 15			
			R.	−31 25	s.w. by w. ½ w.		+8 02	−23 23			
30 P.M.	−66 31	203 06	T.	−30 38	s.w.		+6 39	−23 59			
1842. Jan. 6 P.M.	−66 04	203 17	R.	−26 58	s. ¼ w.	−79 56	+0 28	−26 30	−1 20	−26 59	
			Sm.	−26 38	s. ½ w.		+0 56	−25 42			
			R.	−28 16	s. by w. ¼ w.		+2 20	−25 56			
			Sm.	−28 38	s. by w. ½ w.		+2 46	−25 52			
			R.	−23 42	n. by e.		−1 33	−25 14			
			R.	−27 26	n. by w. ¼ w.		+1 54	−25 32			
			T.	−27 14	n. by w. ½ w.		+2 16	−24 58			
	−66 05	203 13	T.	−30 55	n.w. ¼ n.		+6 26	−25 29			
7 P.M.	−66 20	204 19	T.	−32 04	n.w. ½ w.	−79 45	+6 07	−25 57	−1 20	−26 36	
				−32 41	n.w. ½ w.		+6 07	−26 37			
8 P.M.	−66 14	204 48	R.	−32 34	s.w. by w.		+7 31	−25 03			
	−66 15	204 50	R.	−16 07	e. by s.		−8 28	−24 35			
			R.	−33 01	s.w. by w.		+7 31	−25 30			
		204 49	R.	−28 21	s.s.w. ½ w.		+4 26	−23 56			
9 A.M.	−66 12	204 26	Sm.	−16 58	e.	−79 52	−8 25	−25 23	−1 20	−25 55	
			O.	−16 49	s.e. by e. ½ e.		−7 55	−24 44			
	−66 15	204 26	S.	−16 50	e. by s. ½ s.		−8 24	−25 14			
		204 23	T.	−31 46	s.w.		+6 33	−25 13			
			O.	−30 14	s.w. ½ s.		+5 54	−24 20			
			S.	−17 09	e. ½ s.		−8 26	−25 35			
			T.	−15 31	e. by s. ½ s.		−8 24	−23 55			
			Y.	−15 38	e. ½ s.		−8 26	−24 04			
			W.	−14 22	e. by s. ½ s.		−8 24	−22 46			
	−66 16	204 24	T.	−16 12	e. by s. ½ s.		−8 24	−24 36			

Observations of Declination. (Continued.)

1842.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Jan. 16 P.M.	−65 47	202 13	R.	−22 19	Observed on ice.	....	....	−22 19	−3 03	−25 15	R
			R.	−26 36				−26 36	−0 05		H 162
			R.	−24 45				−24 45	−0 28		H 167
			R.	−24 00				−24 00	−1 20		CCL
			R.	−23 16				−23 16	−1 20		CCL
			R.	−22 58				−22 58	−1 20		CCH
28 P.M.	−67 39	204 24	T.	−29 56	N. by W. ½ W.	−80 34	+2 25	−27 31	−1 20	−27 46	
			T.	−19 02	S.S.E. ½ E.		−4 44	−23 46			
		204 28	R.	−36 04	W. by N. ¼ N.		+8 44	−27 20			
			T.	−17 30	E.N.E.		−8 13	−25 43			
	−67 40	204 27	T.	−17 42	E. ½ S.		−9 12	−26 54			
			R.	−16 49	E. ½ S.		−9 12	−26 01			
			R.	−35 09	S.W. ¼ W.		+7 20	−27 49			
29 A.M.	−67 34	203 59	T.	−27 58	S. ½ W.		+1 00	−26 58			
			T.	−16 57	E. ¾ N.		−8 57	−25 54			
31 A.M.	−67 20	202 20	T.	−28 40	S. by W. ½ W.	−80 44	+3 00	−25 40	−1 20	−27 36	
	−67 21	202 02	T.	−28 20	S. ½ W.		+1 01	−27 19			
			R.	−25 59	S. ½ E.		−1 01	−27 00			
			T.	−26 30	S.		0 0	−26 30			
			T.	−22 51	S. by E. ¾ E.		−3 28	−26 19			
			R.	−24 19	S. by E. ½ E.		−3 00	−27 19			
Feb. 1 P.M.	−67 19	201 56	T.	−20 23	S.S.E. ½ E.		−4 45	−25 08			
			W.	−19 08	S.E. by S.		−5 42	−24 50			
			T.	−34 20	N.W. by W.	−80 44	+7 27	−26 53	−1 20	−28 12	
			R.	−37 09	W. ¾ N.		+9 09	−26 00			
			O.	−34 45	N.W. by W.		+7 27	−26 18			
			T.	−28 10	S. by W.		+2 02	−26 08			
			W.	−29 43	S. by W.		+2 02	−27 41			
			R.	−29 29	N.N.W. ¼ W.		+3 26	−26 03			
			R.	−25 12	N. ½ E.		−0 50	−26 02			
		201 55	R.	−36 14	S.W ½ S.		+6 26	−29 48			
2 A.M.	−67 43	200 00	T.	−31 31	S.S.W.	−81 00	+4 04	−27 27	−1 20	−30 25	
	−68 18	202 24	R.	−39 16	N.W.byW.¾W.		+7 55	−31 21			
	−68 17	202 32	T.	−39 48	W.S.W.		+9 19	−30 29			
3 A.M.	−68 04	199 45	W.	−21 19	S. by E. ¼ E.		−2 34	−23 53			
	−68 03	199 47	T.	−21 36	S.S.E. ½ E.		−4 57	−26 33			
	−68 37	200 03	S.	−21 34	S.E. ½ S.		−6 36	−28 10			
			R.	−22 08	S.E. by S.		−5 51	−27 59			
	−68 41	199 54	R.	−23 06	S.E. ¾ S.		−6 13	−29 19			
			R.	−39 53	W. ¾ S.		+9 42	−30 11			
			W.	−38 58	W. ½ S.		+9 42	−29 16			
			T.	−40 19	W. ½ S.		+9 42	−30 37			
			S.	−40 25	W. ¾ S.		+9 42	−30 43			
			O.	−39 34	W. by S.		+9 42	−29 52			
	−68 44	199 50	R.	−40 56	W. by S. ½ S.		+9 30	−31 26			
4 A.M.	−68 49	199 42	Sm.	−24 47	S. by E. ½ E.	−81 38	−3 20	−28 07	−1 20	−32 33	
	−68 50		T.	−29 49	S. ½ W.		+1 08	−28 41			
	−68 51		O.	−29 42	S. by E.		−2 16	−31 58			
	−68 46	199 48	W.	−37 01	N.N.W. ½ W.		+4 35	−32 26			
			W.	−35 15	N.W. ½ N.		+6 15	−29 00			
			R.	−35 57	N.W. ½ N.		+6 15	−29 42			
			T.	−35 54	N.W. ½ N.		+6 15	−29 39			
	−68 45	199 53	R.	−34 23	N.N.W. ¾ W.		+5 03	−29 20			
	−68 44	199 46	T.	−32 17	N. by W.		+2 16	−30 01			
			R.	−33 05	N. by W. ¼ W.		+2 22	−30 43			
			R.	−38 42	S.W. ½ S.		+7 07	−31 35			
			T.	−38 31	S.W. ¼ S.		+7 31	−31 00			
	−68 45	199 50	R.	−35 32	S.S.W. ¼ W.		+4 52	−30 40			

Observations of Declination. (Continued.)

1842.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Feb. 8. A.M.	−70 07	186 36	S.	−27 52	S.S.E.	−83 39	− 5 37	−33 29	−1 20	−35 42	
			T.	−26 51	S.S.E. ½ E.		− 6 51	−33 42			
			O.	−30 31	S. by E. ¼ E.		− 3 31	−34 02			
	−70 08	186 25	S.	−33 41	S.		0 0	−33 41			
			W.	−30 23	S. by E. ¼ E.		− 3 31	−33 54			
			T.	−29 56	S. by E. ½ E.		− 4 12	−34 08			
		186 24	T.	−33 40	S. ¼ E.		− 0 43	−34 23			
8 P.M.	−70 34	185 47	R.	−32 55	S. by E.		− 2 54	−35 49			
			T.	−33 18	S. by E.		− 2 54	−36 12			
9 A.M.	−70 34	185 33	T.	−52 48	W. ½ N.	−84 00	+14 29	−38 19	−1 20	−38 21	
			W.	−50 28	W. by N.		+14 15	−36 13			
9 P.M.	−70 30	185 25	R.	−50 00	W. ½ N.		+14 29	−35 31			
	−70 38	185 26	O.	−52 27	W. ½ S.		+14 40	−37 47			
	−70 33	185 20	R.	−51 21	W. ¼ S.		+14 41	−36 20			
			T.	−51 05	W. ¼ S.		+14 41	−36 24			
			W.	−52 05	W. ¼ N.		+14 36	−37 29			
			T.	−50 17	W. ¼ N.		+14 36	−35 41			
	−70 31	185 13	R.	−51 58	W. ¼ S.		+14 41	−37 17			
			T.	−52 43	W.		+14 43	−38 00			
			R.	−52 35	W. ¾ N.		+14 22	−38 13			
	−70 26	185 05	R.	−53 52	W. ¼ N.	−83 52	+14 18	−39 34	−1 20	−37 35	
			T.	−51 49	W. ½ N.		+14 11	−37 38			
			R.	−51 12	W. ½ N.		+14 11	−37 01			
	−70 25	185 00	S.	−54 00	W.		+14 25	−39 35			
10 A.M.	−70 22	184 17	T.	−49 11	W. ½ S.		+14 22	−34 49			
			SM.	−49 13	W.		+14 25	−34 48			
			T.	−49 48	W. ½ N.		+14 11	−35 37			
	−70 20	184 10	SM.	−49 51	W. ¾ S.		+14 20	−35 31			
			T.	−47 56	W. by S. ¾ S.		+13 50	−34 06			
	−70 16	183 54	O.	−46 47	S.W. by W. ½ W.		+12 59	−33 48			
			S.	−47 11	W.S.W.	−83 50	+13 34	−33 37	−1 20	−36 28	
			T.	−47 05	S.W. by W. ½ W.		+12 57	−34 08			
			S.	−50 09	W. by S. ½ S.		+13 54	−36 15			
10 P.M.	−70 11	183 52	R.	−27 10	S.E. by S.		− 8 24	−35 34			
	−70 13	183 51	R.	−26 53	S.E.		−10 37	−37 30			
	−70 12	183 50	O.	−50 12	W. by S.		+14 13	−35 59			
			T.	−48 52	W. by S.		+14 13	−34 39			
			R.	−48 27	W. ½ S.		+14 16	−34 11			
			T.	−49 13	W. ¼ N.		+14 12	−35 01			
			W.	−47 54	W. ½ N.		+14 05	−33 49			
	−70 14	183 54	T.	−49 53	W. ¼ N.		+14 12	−35 41			
13 A.M.	−72 10	180 58	S.	−30 58	S.E.	−85 07	−13 19	−44 17	−1 20	−45 37	
16 A.M.	−75 08	173 20	T.	−55 14	S.E. ¾ S.	−87 10	−19 18	−74 32	−1 20	−77 17	
			R.	−56 11	S.E. ½ S.		−20 33	−76 44			
	−75 03	173 03	T.	−56 01	S.E. ½ S.		−20 33	−76 34			
18 P.M.	−76 48	182 33	T.	−85 00	N.	−86 50	0 0	−85 00	−1 20	−86 23	
			R.	−84 09	N. ½ E.		− 2 39	−86 48			
			S.	−88 09	N.		0 0	−88 09			
			T.	−84 23	N.		0 0	−84 23			
			W.	−90 46	N. by W. ½ W.		+ 7 53	−82 53			
	−76 47	182 33	R.	−80 25	N. ½ E.		− 2 39	−83 04			
22 A.M.	−76 21	194 43	T.	−63 58	S.E. ¾ S.	−85 26	−12 25	−76 23	−1 20	−79 57	
	−76 29		O.	−72 18	S.S.E. ½ E.		− 9 49	−82 07			
			S.	−70 54	S.S.E.		− 8 03	−78 57			
			T.	−71 09	S. by E. ½ E.		− 6 05	−77 14			
	−76 32	194 39	T.	−68 08	S.S.E. ¼ E.		− 9 00	−77 08			
			W.	−72 15	S. by E.		− 4 05	−76 20			
	−76 58	194 35	R.	−59 41	E. by S.		−20 00	−79 41			
	−76 57	194 28	T.	−59 00	E. by S.		−20 00	−79 00			
			R.	−59 18	E. by S.		−20 00	−79 18			
			R.	−59 57	E. by S.		−20 00	−79 57			

Observations of Declination. (Continued.)

1842.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
Feb. 23 A.M.	−77° 45′	198° 16′	T.	−96° 30′	s.s.w.	−85° 00′	+7° 08′	−89° 22′	−1° 20′	−88° 08′	
			O.	−96 31	s.s.w. ½ w.		+8 43	−87 48			
			S.	−96 05	s.s.w.		+7 08	−88 57			
			T.	−93 06	s.s.w.		+7 08	−85 58			
			O.	−93 39	s.w. by s.		+10 19	−83 20			
	−77 42	198 00	T.	−94 06	s.s.w. ½ w.		+8 43	−85 23			
			S.	−94 02	s.w. by s.		+10 19	−83 43			
			W.	−98 12	s.w. by s.		+10 19	−87 53			
			T.	−99 25	s.w. by s.		+10 19	−89 06			
	−77 50	197 54	W.	−98 09	s.w. ½ s.		+11 41	−86 28			
23 P.M.	−77 48	197 03	R.	−69 54	E. ½ s.	−85 00	−17 41	−87 35	−1 20	−87 31	
	−77 56	197 40	T.	−69 07	E. ¾ s.		−17 39	−86 46			
	−78 00	197 26	R.	−70 06	E. by s.		−17 37	−87 43			
			T.	−68 51	E. ¾ s.		−17 39	−86 30			
	−78 02	197 24	S.	−70 14	E.		−17 46	−88 00			
	−78 07	197 34	R.	−67 13	E. ½ s.		−17 41	−84 54			
			T.	−66 56	E. ½ s.		−17 41	−84 37			
			S.	−68 23	E.		−17 46	−86 09			
	−78 10	197 43	R.	−67 53	E. ½ s.		−17 41	−85 34			
			T.	−66 26	E. by s.		−17 37	−84 03			
25 A.M.	−75 13	193 50	T.	−82 32	w.	−85 00	+17 46	−64 46	−1 20	−62 17	
			O.	−80 13	w.		+17 46	−62 27			
	−74 40	194 01	R.	−73 01	N.w.byw.½w.		+15 11	−57 50			
	−74 37	194 04	R.	−73 34	w.N.w.		+16 05	−57 29			
	−74 25	194 04	T.	−76 47	w.N.w.		+16 05	−60 42			
		193 55	R.	−76 45	N.w. by w.		+14 17	−62 28			
27 P.M.	−71 59	186 42	T.	−57 42	s.w.byw.¼w.	−84 25	+14 00	−43 42	−1 20	−45 11	
	−71 54	186 30	R.	−57 40	s.w. by w.		+13 40	−44 00			
28 A.M.	−71 11	185 03	T.	−52 06	s.w.byw.½w.	−84 15	+13 51	−38 15	−1 20	−39 20	
	−71 09	184 58	S.	−50 45	w.s.w.		+14 30	−36 15			
			T.	−53 25	s.w.byw.½w.		+13 51	−39 34			
	−71 05	184 45	T.	−53 20	w. ½ s.		+15 19	−38 01			
			R.	−53 16	w.		+15 23	−37 53			
Mar. 1 A.M.	−70 11	180 32	O.	−46 44	w.N.w.	−83 46	+13 52	−32 52	−1 20	−30 50	
			T.	−45 32	w. by N. ½ N.		+14 22	−31 10			
			S.	−44 09	w.N.w.		+13 52	−30 17			
	−70 10	180 29	T.	−46 02	w.N.w.		+13 52	−32 10			
			W.	−45 45	w.N.w.		+13 52	−31 53			
1 P.M.	−69 36	180 02	R.	−24 21	N. by E.	−83 43	−2 47	−27 08			
			S.	−24 00	N. by E.		−2 47	−26 47			
			T.	−24 01	N. by E. ½ E.		−4 10	−28 11			
			O.	−24 05	N. by E. ½ E.		−4 10	−28 15			
	−69 32	180 08	S.	−22 09	N.N.E. ½ E.		−6 45	−28 54			
	−69 33	180 10	T.	−21 28	N.N.E. ½ E.		−6 45	−28 13			
			R.	−21 20	N.N.E. ½ E.		−6 45	−28 05			
2 A.M.	−68 50	182 38	W.	−22 58	N.N.E.	−82 23	−4 31	−27 29	−1 20	−27 32	
	−68 44	182 43	T.	−22 15	N.N.E.		−4 31	−26 46			
			W.	−22 09	N.N.E.		−4 31	−26 40			
	−68 40	182 53	T.	−23 34	N. by E. ½ E.		−3 24	−26 58			
2 P.M.	−67 53	183 44	R.	−22 49	N. by E. ¾ E.		−3 57	−26 46			
	−67 52		S.	−20 18	N.E. by N.		−6 34	−26 52			
	−67 49	184 05	T.	−17 56	N.E.		−8 27	−26 23			
	−67 47	184 25	T.	−18 59	N.N.E. ½ E.		−5 33	−24 32			
			R.	−19 10	N. by E. ¾ E.		−3 57	−23 07			
			W.	−16 49	N.E.		−8 27	−25 16			
			R.	−18 58	N.E. by N.		−6 34	−25 32			
	−67 45	184 15	R.	−21 25	N.E. by N.		−6 34	−27 59			

Observations of Declination. (Continued.)

1842.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
March 3 A.M.	−67 34	185 19	O.	−17 21	N.E. ½ E.	−82 00	− 8 41	−26 02	−1 20	−27 32	
	−67 28	185 39	R.	−18 06	N.E. ½ E.		− 8 41	−26 47			
5 A.M.	−67 20	187 56	T.	−16 16	E. by N.	−81 10	−10 23	−26 39			
			W.	−14 45	E. ½ N.		−10 35	−25 20			
6 A.M.	−65 27	191 35	Sm.	−19 52	N. by E.	−79 25	− 1 34	−21 26	−1 20	−23 40	
	−65 21	191 45	T.	−21 59	N. ½ E.		− 0 47	−22 46			
6 P.M.	−65 00	192 42	T.	−21 38	N. ¾ E.		− 1 10	−22 48			
		192 40	W.	−20 48	N. by E.		− 1 34	−22 22			
			T.	−20 15	N. by E.		− 1 34	−21 49			
			R.	−20 33	N. by E.		− 1 34	−22 07			
	−64 58	192 44	T.	−21 55	N. ¾ E.		− 1 10	−23 05			
7 P.M.	−63 33	194 53	R.	−15 05	S.E. ½ S.	−78 17	− 5 32	−20 37	−1 20	−21 57	
8 A.M.	−62 33	195 56	W.	−17 12	N. by E.	−77 23	− 1 17	−18 29	−1 20	−19 51	
			T.	−19 19	N. ¾ E.		− 0 58	−20 17			
8 P.M.	−62 11	196 26	T.	−11 28	S.E.		− 5 44	−17 12			
		196 29	T.	−15 05	N N.E. ½ E.		− 3 07	−18 12			
			R.	−15 53	N.N.E.		− 2 32	−18 25			
9 A.M.	−61 15	198 29	T.	−14 36	N.E. by N.	−76 09	− 3 20	−17 56	−1 20	−18 42	
			Sm.	−13 54	N.E. by N.		− 3 20	−17 14			
9 P.M.	−60 54	199 40	W.	−12 25	N.E. ¾ E.		− 5 00	−17 25			
	−60 51	199 47	R.	−12 19	N.E. by E.		− 5 12	−17 30			
			S.	−12 12	N.E. by E.		− 5 12	−17 23			
			W.	−14 24	N.E.		− 4 22	−18 46			
	−60 50	199 49	R.	−11 40	N.E. by E.		− 5 12	−16 52			
	−60 47	200 20	R.	−10 12	E.N.E.		− 6 00	−16 12			
10 A.M.	−60 34	202 42	S	−10 21	E.N.E.	−74 15	− 5 30	−15 51	−1 20	−17 31	
			O.	−10 09	E.N.E.		− 5 30	−15 39			
	−60 32	203 08	T.	−11 10	E.N.E.		− 5 30	−16 40			
10 P.M.	−60 18	206 10	T.	−10 34	E. by N.		− 6 00	−16 34			
12 A.M.	−60 17	212 56	S.	−10 54	E. by N.	−73 55	− 5 34	−16 28	−1 20	−17 01	
			O.	− 9 58	E. by N.		− 5 34	−15 30			
			T.	− 8 29	E. by N. ½ N.		− 5 20	−13 49			
	−60 13	213 07	S.	−11 19	E. by N.		− 5 34	−16 53			
14 P.M.	−59 15	219 01	T.	− 8 53	N.E.	−73 56	− 3 37	−12 30	−1 20	−15 30	
			T.	− 8 33	N.E. by E.		− 4 26	−12 59			
		219 14	T.	− 8 10	N.E. by E.		− 4 26	−12 36			
15 A.M.	−58 44	221 51	T.	−10 06	E. by N. ¼ N.	−73 30	− 5 10	−15 16			
			S.	−12 31	E.N.E.		− 4 50	−17 21			
	−58 42	221 59	T.	− 9 23	E.N.E.		− 4 50	−14 13			
16 P.M.	−59 04	229 00	R.	−11 08	E. ½ S.	−73 00	− 5 26	−16 34	−1 20	−17 49	
			S.	−11 15	E. ½ S.		− 5 26	−16 41			
			O.	−10 47	E. ½ S.		− 5 26	−16 13			
			T.	−11 03	E. ½ S.		− 5 26	−16 29			
18 A.M.	−60 14	236 32	S.	−13 59	E.	−73 00	− 5 24	−19 23	−1 20	−20 56	
			O.	−15 28	E.		− 5 24	−20 52			
	−60 13	236 33	T.	−13 10	E.		− 5 24	−18 34			
20 P.M.	−59 17	245 40	R.	−14 40	E.N.E.	−71 33	− 4 14	−18 54	−1 20	−20 14	
22 A.M.	−58 40	251 52	T.	−15 41	E. by N.	−70 51	− 4 29	−20 10	−1 20	−21 47	
			W.	−15 48	E. by N.		− 4 29	−20 17			
			S.	−16 24	E. by N.		− 4 29	−20 53			
23 A.M.	−58 42	254 46	T.	−17 28	E. ½ N.	−70 11	− 4 26	−21 54	−1 20	−23 28	
			W.	−17 40	E. ½ N.		− 4 26	−22 06			
	−58 43	254 50	T.	−18 20	E.		− 4 35	−22 55			
23 P.M.	−58 38	255 34	R.	−17 58	N.E. by E. ½ E.		− 3 40	−21 38			
24 A.M.	−58 46	258 07	T.	−18 40	E.	−69 46	− 4 29	−23 09	−1 20	−25 25	
			O.	−19 41	E. ½ N.		− 4 21	−24 02			
			S.	−20 42	E. ½ N.		− 4 21	−25 03			

Observations of Declination. (Continued.)

1842.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° '	° '		° '		° '	° '	° '	° '	° '	
Mar. 26 A.M.	−59 00	268 07	T.	−20 21	E. by N. ½ N.	−67 38	−3 32	−23 53	−1 20	−26 17	
			W.	−21 51	E. by N. ½ N.		−3 32	−25 23			
		268 10	T.	−22 06	E. by N. ½ N.		−3 32	−25 38			
26 P.M.	−59 02	268 40	T.	−22 17	E.N.E.		−3 24	−25 41			
			R.	−22 10	E.N.E.		−3 24	−25 34			
		268 45	T.	−21 40	E.N.E.		−3 24	−25 04			
			R.	−21 31	E.N.E.		−3 24	−24 55			
			O.	−20 32	E.N.E.		−3 24	−23 56			
		269 10	R.	−21 02	E.N.E.		−3 24	−24 26			
27 A.M.	−59 02	272 04	Sm.	−22 15	E.N.E.	−67 00	−3 16	−25 31	−1 20	−26 51	
28 A.M.	−58 50	275 44	S.	−21 42	N.E. by E. ½ E.	−65 30	−2 50	−24 32	−1 20	−26 18	
			O.	−21 37	N.E. by E. ½ E.		−2 50	−24 27			
			W.	−24 04	N.E. by E.		−2 36	−26 40			
	−58 52	276 15	T.	−22 51	N.E. by E.		−2 36	−25 27			
	−58 54	276 53	R.	−21 06	N.E. by E.		−2 36	−23 42			
29 A.M.	−58 24	280 05	T.	−22 22	N.E. ½ E.	−64 50	−2 15	−24 37	−1 20	−25 04	
29 P.M.	−58 20	280 34	R.	−20 55	N.E.		−2 02	−22 57			
	−58 19	280 31	T.	−22 12	N.E. ½ E.		−2 15	−24 27			
			W.	−21 09	N.E. ½ E.		−2 15	−23 24			
		280 32	T.	−21 01	N.E. ½ E.		−2 15	−23 16			
30 A.M.	−58 30	282 07	T.	−22 52	E.N.E.	−63 40	−2 47	−25 39	−1 20	−26 14	
			Sm.	−23 19	N.E. by E. ½ E.		−2 35	−25 54			
			O.	−21 57	E.N.E.		−2 47	−24 44			
			S.	−21 46	E.N.E.		−2 47	−24 33			
			T.	−21 53	E.N.E.		−2 47	−24 40			
	−58 29	282 01	S.	−22 24	N.E. by E.		−2 23	−24 47			
			W.	−20 46	E. by N. ½ N.		−2 58	−23 44			
			T.	−22 21	E.N.E.		−2 47	−25 08			
			S.	−22 09	N.E. by E.	−63 00	−2 18	−24 27	−1 20	−26 18	
		282 22	T.	−23 34	N.E. ½ E.		−2 04	−25 38			
			S.	−21 39	N.E. ½ E.		−2 04	−23 43			
	−58 28	282 24	T.	−23 30	N.E. ½ E.		−2 04	−25 34			
31 A.M.	−58 40	285 29	W.	−24 06	N.E. ½ N.		−1 36	−25 42			
			S.	−22 42	N.E. by N.		−1 23	−24 05			
	−58 32	285 30	T.	−24 02	N.E. ½ N.		−1 36	−25 38			
April 5 A.M.	−52 56	300 18	T.	−15 31	N.N.E.	−53 54	−0 33	−16 04	−1 20	−16 29	
			R.	−15 26	N.N.E.		−0 33	−15 59			
5 P.M.	−52 14	300 50	T.	−14 33	N. by E.		−0 16	−14 49			
6 A.M.	−51 50	301 43	T.	−12 06	E. by S.	−52 30	−2 16	−14 22			
			T.	−12 32	E. by S.		−2 16	−14 48			
			T.	−15 34	N.N.W. ½ W.		+0 38	−14 56			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
Aug. 10.	−33° 44′	166° 30′	C.	−13° 11′	N. 70° E.	−60° 10′	−2° 04′	−15° 15′	+1° 30′	−13° 40′	
			C.	−14 20	N. 65° E.		−1 53	−16 13			
			C.	−13 12	N. 61° E.		−2 08	−15 20			
			C.	−11 15	S. 82° E.		−2 57	−14 12			
			C.	−13 13	N. 67° E.		−1 59	−15 12			
	−34 00	166 26	Cr.	−11 30	E. by N.		−2 39	−14 09			
			Cr.	−12 04	E.		−2 52	−14 56			
			Cr.	−11 33	E.S.E.		−2 59	−14 32			
			Cr.	−12 29	S.E. by E.		−2 50	−15 19			
11.	−33 32	167 35	C.	−14 56	N. 77° E.	−59 40	−2 36	−17 32	+1 30	−15 02	
			C.	−14 34	E.		−2 49	−17 23			
			C.	−14 16	N. 73° E.		−2 27	−16 43			
			C.	−13 38	N. 78° E.		−2 36	−16 14			
			C.	−14 00	E.		−2 49	−16 49			
			C.	−12 41	S. 85° E.		−2 43	−15 24			
			C.	−13 28	N. 72° E.		−2 25	−15 53			
			C.	−13 33	N. 72° E.		−2 25	−15 58			
			Cr.	−13 31	E.		−2 49	−16 20			
12.	−32 53	169 30	C.	−13 57	N. 56° E.		−1 56	−15 53			
			C.	−15 39	N. 53° E.		−1 50	−17 29			
			Cr.	−15 09	N.E.		−1 34	−16 43			
15.	−33 56	171 50	C.	−13 22	E. ½ S.	−58 10	−2 43	−16 05	+1 30	−13 45	
			C.	−11 27	E. by S.		−2 47	−14 14			
16.	−34 20	172 45	C.	−13 53	E.		−2 40	−16 33			
			C.	−14 08	E.		−2 40	−16 48			
			C.	−16 20	N. 26° W.		+0 46	−15 34			
			C.	−14 30	N. 38° W.		+1 15	−13 15			
			C.	−12 16	E.S.E.		−2 47	−15 03			
			Cr.	−15 30	N.W. by N.		+1 04	−14 26			
			Cr.	−12 34	E. by S.		−2 47	−15 21			
17.	−34 36	173 50	C.	−12 11	S. 83° E.	−58 10	−2 45	−14 56	+1 30	−13 42	
			C.	−12 24	E. by S. ½ S.		−2 47	−15 11			
			C.	−13 20	E. by S. ½ S.		−2 47	−16 07			
			C.	−11 38	E. by S. ½ S.		−2 47	−14 25			
	−34 17	173 35	Cr.	−12 35	E. by S.		−2 47	−15 22			
Nov. 24.	−36 17	177 12	Cr.	−13 51	E.S.E.	−59 40	−2 45	−16 36	+1 30	−14 55	
25.	−38 06	179 40	C.	−15 02	S.E. ½ E.	−60 15	−2 30	−17 32			
			C.	−14 57	S.E. ½ E.		−2 30	−17 27			
			C.	−15 53	S.E.		−2 22	−18 15			
			Cr.	−14 50	S.E. by S.		−1 56	−16 46			
	−38 17	179 54	Cr.	−14 26	S.E. by E.		−2 39	−17 05			
	−38 26	179 54	Cr.	−12 07	S.E. by E.		−2 39	−14 46			
	−38 23	179 54	C.	−13 23	S.E. by E.		−2 39	−16 02			
			C.	−11 33	S.E. by E.		−2 39	−14 12			
			C.	−12 50	S.E. by E. ½ E.		−2 43	−15 33			
26.	−39 03	182 33	Cr.	−13 59	E. by S.	−61 00	−2 54	−16 53	+1 30	−16 55	
			C.	−13 18	S.E. by E. ½ E.		−2 48	−16 06			
			C.	−15 57	S.E.		−2 26	−18 23			
			C.	−15 47	S.E. by E. ½ E.		−2 48	−18 35			
			Cr.	−14 19	S.E. by E.		−2 44	−17 03			
			Cr.	−13 43	E.S.E.		−2 53	−16 36			
			Cr.	−12 32	E.S.E.		−2 53	−15 25			
			Cr.	−13 22	E.S.E.		−2 53	−16 15			
28.	−40 38	183 05	C.	−18 06	S. by E.	−62 00	−0 45	−18 51			
			C.	−15 51	S.E.		−2 31	−18 22			
			Cr.	−16 32	S.E.		−2 31	−19 03			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Dec. 9.	−52 27	198 14	Cr.	−15 16	E.S.E.	−70 15	− 4 20	−19 36	+1 30	−14 54	
12.	−53 03	204 50	C.	−12 10	E.S.E.		− 4 20	−16 30			
			C.	−11 33	S.E. by E. ¾ E.		− 4 15	−15 58			
			C.	−10 32	E. by S. ¾ S.		− 4 23	−14 55			
			C.	−10 52	E. by S. ¾ S.		− 4 23	−15 15			
			C.	−11 00	E.S.E.		− 4 20	−15 20			
	−53 18	205 46	C.	−11 32	E.S.E.		− 4 20	−15 52			
			C.	−12 32	E.S.E.		− 4 20	−16 52			
	−53 06	205 24	Cr.	−12 11	E.S.E.		− 4 20	−16 31			
			Cr.	−12 31	S.E. by E.		− 4 01	−16 32			
	−53 21	205 24	Cr.	−12 42	E.S.E.		− 4 20	−17 02			
14.	−56 18	211 30	C.	−13 27	S.E. ¼ E.	−72 00	− 3 57	−17 24	+1 30	−15 14	
			C.	−12 37	S.E. ¾ E.		− 4 13	−16 50			
			C.	−13 57	S.E.		− 3 49	−17 46			
			C.	−13 54	S.E. ½ S.		− 3 26	−17 20			
	−56 24	211 45	C.	−12 24	E.		− 4 43	−17 07			
			C.	−12 01	E. ¼ N.		− 4 35	−16 36			
			C.	−21 03	S.W. ¼ W.		+ 3 57	−17 06			
			C.	−13 05	N.E. ¼ N.		− 2 44	−15 49			
	−56 10	211 37	Cr.	−13 15	S.E. by S.		− 3 03	−16 18			
			Cr.	−12 34	S.E. by S.		− 3 03	−15 37			
			Cr.	−11 19	S.E. by S.		− 3 03	−14 22			
	−56 29	211 50	Cr.	−14 50	S.E. by S.		− 3 03	−17 53			
			Cr.	−14 52	S.S.E.		− 2 09	−17 01			
			Cr.	−13 15	S.E.		− 3 49	−17 04			
15.	−56 55	212 00	C.	−14 51	S.S.E. ½ E.	−72 30	− 2 40	−17 31	+1 30	−15 14	
			C.	−13 35	S.E. ½ S.		− 3 31	−17 06			
			C.	−13 48	S.E. ¾ S.		− 3 20	−17 08			
			C.	−13 42	S.E. ¾ S.		− 3 20	−17 02			
	−57 09	212 26	C.	−15 01	S.S.E.		− 2 12	−17 13			
			C.	−13 59	S.S.E.		− 2 12	−16 11			
			C.	−13 30	S.S.E. ¼ E.		− 2 25	−15 55			
			Cr.	−13 39	S.S.E.		− 2 12	−15 51			
			Cr.	−14 43	S.S.E.		− 2 12	−16 55			
			Cr.	−14 15	S.S.E.		− 2 12	−16 27			
16.	−58 21	213 00	C.	−16 32	S. by E. ¾ E.	−73 55	− 2 06	−18 38	+1 30	−17 34	
			C.	−17 39	S. by E. ¼ E.		− 1 31	−19 10			
			C.	−15 52	S.S.E.		− 2 23	−18 15			
			C.	−16 11	S. by E. ¾ E.		− 2 06	−18 17			
			C.	−16 05	S.S.E.		− 2 23	−18 28			
			C.	−15 42	S.S.E		− 2 23	−18 05			
			Cr.	−15 47	S.S.E.		− 2 23	−18 10			
			Cr.	−18 43	S.S.E.		− 2 23	−21 06			
			Cr.	−19 07	S.S.E.		− 2 23	−21 30			
17.	−60 28	213 40	Cr.	−15 27	S.S.E.	−75 40	− 2 38	−18 05	+1 30	−20 03	
18.	−62 53	212 48	C.	−22 22	S. by W.	−76 50	+ 1 29	−20 53			
			C.	−24 19	S. ½ W.		+ 0 44	−23 35			
			C.	−20 41	S. by E. ¼ E.		− 1 52	−22 33			
			C.	−21 10	S. ½ E.		− 0 44	−21 54			
	−62 56	212 00	C.	−28 15	S.W. by W.		+ 5 54	−22 21			
			C.	−27 18	S.W. by W.		+ 5 54	−21 24			
			C.	−27 54	S.W. ¾ W.		+ 5 44	−22 10			
			C.	−28 15	S.W. by W.		+ 5 54	−22 21			
			C.	−27 49	S.W. by W. ½ W.		+ 6 11	−21 38			
			C.	−27 16	S.W.		+ 5 08	−22 08			
	−63 01	211 30	C.	−23 57	S.S.W. ½ W.		+ 3 32	−20 25			
			C.	−24 06	S.S.W.		+ 2 58	−21 08			
			C.	−24 02	S.S.W.		+ 2 58	−21 04			
	−62 56	212 00	Cr.	−26 48	S.W.		+ 5 08	−21 40			

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Dec. 19.	−63 16	210 00	C.	−28 20	s.s.w. ¾ w.	−77 36	+ 4 02	−24 18	+1 30	−20 56	
			C.	−26 10	s.s.w. ¼ w.		+ 3 27	−22 43			
	−63 23	209 40	C.	−31 10	w. by s. ½ s.		+ 6 54	−24 16			
			C.	−25 18	s. by w. ½ w.		+ 2 21	−22 57			
			C.	−23 47	s. ¼ w.		+ 0 23	−23 24			
			C.	−21 21	s.		0 0	−21 21			
			C.	−28 21	w.s.w.		+ 6 47	−21 34			
			C.	−29 18	s.w.		+ 5 25	−23 53			
			C.	−26 15	s.s.w. ½ w.		+ 3 46	−22 29			
			C.	−25 04	s.s.w.		+ 3 08	−21 56			
			C.	−27 23	s.w. ¼ w.		+ 5 38	−21 45			
	−63 17	210 14	Cr.	−24 51	s.w. by s.		+ 4 20	−20 31			
			Cr.	−25 00	s. 18° w.		+ 2 35	−22 25			
			Cr.	−27 16	s. 40° w.		+ 4 52	−22 24			
	−63 23	209 40	Cr.	−27 06	s.s.w.		+ 3 08	−23 58			
			Cr.	−28 50	s. 78° w.		+ 7 02	−21 48			
			Cr.	−26 45	s. 78° w.		+ 7 02	−19 43			
21.	−64 48	206 10	C.	−22 59	s. by e. ¼ e.	−78 30	− 2 04	−25 03	+1 30	−22 55	
			C.	−22 36	s.s.e.		− 3 17	−25 53			
			C.	−25 09	s. ¼ w.		+ 0 25	−24 44			
			C.	−24 11	s. ¾ e.		− 1 15	−25 26			
			C.	−28 03	s.s.w.		+ 3 17	−24 46			
			C.	−23 49	s.		0 0	−23 49			
			C.	−26 53	s. by w. ½ w.		+ 2 28	−24 25			
			C.	−23 09	s. ½ e.		− 0 50	−23 59			
			C.	−20 51	s. ½ e.		− 0 50	−21 41			
22.	−65 21	205 20	C.	−25 11	s.	−79 20	0 0	−25 11	+1 30	−24 27	
			C.	−25 56	s.		0 0	−25 56			
			C.	−27 31	s. ¾ w.		+ 1 20	−26 11			
			Cr.	−27 12	s. by w.		+ 1 48	−25 24			
			Cr.	−27 32	s.		0 0	−27 32			
24.	−65 58	204 00	C.	−26 57	s. by w. ½ w.	−79 40	+ 2 42	−24 15			
1842.			Cr.	−31 30	s.s.w. ½ w.		+ 4 19	−27 11			
Jan. 6.	−66 10	203 37	C.	−23 15	n.e. ¼ n.	−79 56	− 5 26	−28 41	+1 07	−27 24	Card P.
			C.	−29 29	s.		0 0	−29 29			
			C.	−27 27	s. ½ e.		− 0 57	−28 24			
			C.	−27 10	s. ¾ e.		− 1 25	−28 35			
			C.	−28 02	s. ¼ e.		− 0 28	−28 30			
			C.	−29 38	s. by w.		+ 1 54	−27 44			
			Cr.	−31 14	n.n.w.		+ 3 00	−28 14			
9.	−66 02	204 00	C.	−34 06	s.w. ¼ s.	−79 52	+ 6 14	−27 52	+1 07	−26 48	
			C.	−20 52	e.s.e.		− 8 14	−29 06			
			C.	−34 46	s.w.by w.½w.		+ 7 58	−26 48			
			C.	−20 09	e. ½ s.		− 8 32	−28 41			
			C.	−34 42	s.w. ½ s.		+ 5 54	−28 48			
			C.	−35 52	w. by s.		+ 8 32	−27 20			
			C.	−23 47	s.e. by s.		− 5 13	−29 00			
			C.	−20 29	s.e. ¾ e.		− 7 18	−27 47			
			C.	−33 58	s.w. ¾ w.		+ 7 18	−26 40			
			C.	−21 37	s.e. ¾ e.		− 7 18	−28 55			
			C.	−33 55	s.w. ¾ w.		+ 7 18	−26 37			
			C.	−34 19	s.w. ¾ w.		+ 7 18	−27 01			
			C.	−20 34	s.e. ¾ e.		− 7 18	−27 52			
			Cr.	−34 41	s.w.		+ 6 34	−28 07			
			Cr.	−19 20	e.s.e.		− 8 14	−27 34			
			Cr.	−34 20	s.w. ½ w.		+ 7 03	−27 17			
			Cr.	−19 35	e. ½ s.		− 8 32	−28 07			
			Cr.	−20 54	s.e. by e. ¾ e.		− 8 04	−28 58			

Observations of Declination. (Continued.)

1842.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Jan. 10.	−65 58	203 54	C.	−19 32	E. by N.	−79 48	−8 13	−27 45	+1 07	−25 00	
			C.	−34 59	W. by S.		+8 31	−26 28			
			C.	−18 30	E. ¼ S.		−8 31	−27 01			
			C.	−33 40	S.W. by W. ¼ W.		+7 44	−25 56			
			C.	−34 14	S.W. ¾ W.		+7 20	−26 54			
			C.	−33 09	S.W. ½ W.		+7 35	−25 34			
			C.	−32 30	S.W. ½ S.		+7 02	−25 28			
			C.	−30 16	S.S.W. ¼ W.		+4 01	−26 15			
			C.	−33 04	S.W. by W		+7 34	−25 30			
			C.	−32 47	W. by S.		+8 32	−24 15			
			C.	−31 04	S.S.W. ¾ W.		+4 48	−26 16			
			C.	−32 00	S.S.W. ¾ W.	−79 48	+4 48	−27 12	+1 07		
			Cr.	−23 04	S.E. ½ S.		−7 02	−30 06			
			Cr.	−34 10	W.S.W.		+8 12	−25 58			
			Cr.	−19 17	S.E.		−6 32	−25 49			
			Cr.	−16 56	S.E. by E.		−7 34	−24 30			
			Cr.	−19 00	E.S.E.		−8 12	−27 12			
			Cr.	−19 31	E.S.E.		−8 12	−27 43			
			Cr.	−18 33	E. by S.		−8 31	−27 04			
			Cr.	−21 18	S.E.		−6 32	−27 50			
			Cr.	−19 20	E. by N.		−8 13	−27 33			
			Cr.	−18 52	E.S.E.		−8 12	−27 04			
11.	−65 57	203 40	C.	−28 13	N. ¾ W.	−79 48	+1 09	−27 04	+1 07	−26 24	
			C.	−34 41	W. by S. ½ S.		+8 21	−26 20			
			C.	−29 53	S. ¼ W.		+1 26	−28 27			
			C.	−30 13	S. by W. ½ W.		+2 44	−27 29			
			Cr.	−26 44	S.		0 0	−26 44			
			Cr.	−26 45	S.		0 0	−26 45			
12.	−65 46	203 22	Cr.	−35 16	S.W.		+6 32	−28 44			
			Cr.	−38 22	S.W. by W.		+7 34	−30 48			
13.	−66 10	202 40	C.	−26 00	S. ¼ E.		−1 26	−27 26			
			C.	−23 36	S. by E.		−1 52	−25 28			
			Cr.	−25 26	S.		0 0	−25 26			
14.	−66 00	202 30	C.	−26 13	S. by E. ½ E.		−2 44	−28 57			
			C.	−28 28	S. ½ W.		−0 55	−27 33			
			C.	−20 54	E.N.E.		−7 34	−28 28			
			C.	−20 30	N.E. by E.		−6 42	−27 12			
28.	−67 40	204 10	Cr.	−30 54	S. ½ W.	−80 34	+1 01	−29 53	+1 07	−28 19	
			Cr.	−29 04	S. ¾ E.		−1 30	−30 34			
			C.	−31 48	S. ¾ W.		+1 30	−30 18			
			C.	−26 53	N. ½ E.		−0 50	−27 43			
			C.	−33 38	N.W. ¼ N.		+5 52	−27 46			
			C.	−36 47	S.W. ¼ S.		+6 38	−30 09			
			C.	−35 19	S.W. by S.		+5 36	−29 43			
			C.	−34 15	S.S.W.		+3 53	−30 22			
			C.	−19 11	E. ¾ S.		−9 14	−28 25			
29.	−67 36	204 00	Cr.	−21 47	E. by S.	−80 40	−9 20	−31 07	+1 07	−28 37	
			Cr.	−35 06	S.S.W. ¼ W.		+4 20	−30 46			
31.	−67 16	202 10	C.	−32 27	S.S.W.	−80 45	+3 57	−28 30			
			C.	−26 24	S. by E. ½ E.		−2 58	−29 22			
			C.	−31 53	S. ½ W.		+1 02	−30 51			
			C.	−31 04	S. ¾ W.		+1 33	−29 31			
			C.	−29 03	S. ½ W.		+1 02	−28 01			
			C.	−31 39	S. by W.		+2 01	−29 38			
			C.	−32 19	S. ¾ W.		+1 33	−30 46			
	−67 13	202 35	Cr.	−34 04	S.S.W. ¼ W.		+4 20	−29 44			
			Cr.	−32 40	S.S.W.		+3 57	−28 43			

Observations of Declination. (Continued.)

1842.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Feb. 10.	−70 14	184 00	C.	− 53 45	w.	−83 45	+14 07	−39 38	+1 30	−37 19	
			C.	− 51 09	s.w.byw.¾w.		+13 03	−38 06			
			C.	− 28 40	s.e. ¼ e.		−10 54	−39 34			
			C.	− 28 57	s.e. by e.		−12 05	−41 02			
			C.	− 29 12	s.e. by e.		−12 05	−41 17			
			C.	− 54 07	w. by s. ½ s.		+13 42	−40 25			
			C.	− 52 41	w. ¾ s.		+14 04	−38 37			
			C.	− 52 44	w. by s.		+14 02	−38 42			
			C.	− 51 25	w. ¼ s.		+14 05	−37 20			
			C.	− 50 32	w. by s.		+14 02	−36 30			
			C.	− 50 33	w.n.w.		+12 43	−37 50			
			C.	− 37 01	n. ½ e.		− 1 17	−38 18			
			C.	− 38 12	n. by w.		+ 2 34	−35 38			
			Cr.	− 29 28	s.e. by s.		− 8 17	−37 45			
			Cr.	− 28 15	s.e. ½ e.		−11 17	−39 32			
			Cr.	− 53 43	w. ½ s.		+14 05	−39 38			
			Cr.	− 54 05	w. by s.		+14 02	−40 03			
12.	−71 04	180 46	C.	− 30 39	s.e. ¼ s.	−84 30	−11 16	−41 55	+1 30	−40 45	
			C.	− 29 45	s.e.		−11 53	−41 38			
			C.	− 31 59	s.e. by s.		− 9 24	−41 23			
			C.	− 32 18	s.e. ¾ s.		−10 00	−42 18			
			Cr.	− 32 09	s.e.		−11 53	−44 02			
14.	−73 14	181 08	C.	− 37 39	s. 42° e.	−86 00	−15 24	−53 03	+1 30	−51 48	
			Cr.	− 39 01	s.e. ½ s.		−14 32	−53 33			
16.	−75 04	173 20	C.	− 59 26	s.e. by s.	−87 00	−18 03	−77 29	+1 30	−76 03	
			C.	− 40 57	s.e. by e.		−27 15	−68 12			
17.	−76 04	176 00	C.	− 56 12	e. ¾ n.	−87 00	−30 03	−86 15			
			C.	− 56 34	n.e. by e.		−24 47	−81 21			
			C.	− 58 13	n.e. ¾ e.		−23 47	−82 00			
18.	−76 54	182 17	C.	− 80 43	n. ¼ e.	−86 50	− 1 19	−82 02	+1 30	−82 28	
			C.	− 75 23	n. ¼ w.		+ 1 19	−74 04*			
			C.	− 74 51	s. 25° e.		−13 23	−88 14			
			C.	− 75 01	n. by e. ¼ e.		− 6 36	−81 37			
20.	−76 12	191 40	C.	− 58 32	n.e.	−85 55	−15 00	−73 32	+1 30	−70 22	
			C.	− 51 19	n.e.by e. ½ e.		−18 53	−70 12			
22.	−76 32	194 40	C.	− 72 15	s.s.e. ¼ e.	−85 30	− 8 47	−81 02	+1 30	−81 23	
			C.	− 74 30	s.s.e.		− 7 54	−82 24			
			C.	− 72 24	s.e. by s.		−11 26	−83 50			
	−77 00		C.	− 60 26	e.s.e.		−18 42	−79 08			
			C.	− 72 10	e.s.e.		−18 42	−90 52			
			C.	− 65 19	e.s.e.		−18 42	−84 01			
	−76 32		C.	− 72 44	s.s.e. ¼ e.		− 8 47	−81 31			
	−77 00		C.	− 60 43	e. by s.		−19 36	−80 19			
23.	−78 00	198 32	C.	−110 25	w. by n. ¾ n.	−85 30	+18 19	−92 06	+1 30	−88 01	
	−77 55	197 48	C.	− 70 48	e. ½ s.		−19 42	−90 30			
			C.	− 69 12	e. ½ s.		−19 42	−88 54			
			C.	− 70 07	e. ½ s.		−19 42	−89 49			
			C.	− 70 25	e. ½ s.		−19 42	−90 07			
			C.	−108 56	w. ½ n.		+19 33	−89 23			
			C.	−103 22	w.n.w.		+17 59	−85 23			
	−78 04		Cr.	− 70 09	e. by s.		−19 46	−89 55			
24.	−77 32	200 00	Cr.	− 95 35	n.w.	−85 00	+12 05	−83 30	+1 30	−64 33	
25.	−75 22	194 00	C.	− 84 54	w. ½ n.		+17 30	−67 24			
	−74 31	193 50	C.	− 79 11	n. 75° w.		+16 57	−62 14			
			Cr.	− 71 00	n.w.		+12 05	−58 55			
			Cr.	− 56 32	n. ½ e.		− 1 38	−58 10			
28.	−71 00	184 10	C.	− 56 04	w.	−84 00	+14 43	−41 21	+1 30	−38 26	
			C.	− 55 15	w. ¼ n.		+14 29	−40 46			
	−70 54	183 50	Cr.	− 52 17	w. by s.		+14 37	−37 40			

* Doubtful; omitted in the mean.

Observations of Declination. (Continued.)

1842.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
Mar. 1.	−70° 10′	180° 20′	C.	−46° 03′	W. by N. ½ N.	° ′ −83 45	+14° 23′	−31° 40′	° ′ +1 30	° ′ −31 26	
			C.	−48 05	W.N.W.		+13 52	−34 13			
			Cr.	−47 46	W. by N.		+14 52	−32 54			
2.	−67 54	183 40	C.	−26 18	N.N.E.	−82 20	− 4 27	−30 45	+1 30	−28 50	
			C.	−24 31	N.E. by N.		− 6 31	−31 02			
			C.	−25 00	N. by E. ½ E.		− 3 21	−28 21			
	−68 24	183 20	Cr.	−26 47	N.N.E.		− 4 27	−31 14			
3.	−67 30	185 00	C.	−22 20	N.E. ¾ E.	−82 00	− 9 04	−31 26	+1 30	−29 46	
			C.	−19 15	N.E. ¼ N.		− 7 30	−26 45			
			C.	−24 24	N.E. ½ N.		− 7 04	−31 28			
			C.	−23 27	E.N.E.		−10 37	−34 04			
			C.	−24 07	N.E.		− 7 56	−32 03			
			Cr.	−25 40	N.N.E. ½ E.		− 5 12	−30 52			
			Cr.	−22 50	N.E. by E.		− 9 26	−32 16			
5.	−67 19	187 25	C.	−25 52	N. ½ W.	−81 10	+ 0 57	−24 55	+1 30	−25 02	
			Cr.	−26 54	N. by W.		+ 1 54	−25 00			
6.	−65 10	191 46	C.	−24 59	N. by E.	−79 30	− 1 35	−26 34			
			C.	−24 14	N. by E. ½ E.		− 2 21	−26 35			
			Cr.	−25 43	N.N.E.		− 3 08	−28 51			
	−64 56	192 24	Cr.	−27 15	N.		0 0	−27 15			
8.	−62 26	195 40	C.	−20 31	N. ¾ E.	−77 30	− 0 58	−21 29	+1 30	−19 41	
			C.	−22 33	N.		0 0	−22 33			
			Cr.	−18 16	N. by E.		− 1 18	−19 34			
			Cr.	−22 28	N. by W.		+ 1 18	−21 10			
9.	−61 00	199 00	C.	−17 27	N.E.	−76 10	− 4 20	−21 47	+1 30	−19 49	
			C.	−14 35	E.N.E.		− 5 55	−20 30			
			Cr.	−17 46	N.E.		− 4 20	−22 06			
			Cr.	−15 00	E.N.E.		− 5 55	−20 55			
10.	−60 20	205 36	C.	−15 04	E. by N. ½ N.	−75 15	− 5 45	−20 49	+1 30	−18 20	
			C.	−14 25	E.N.E.		− 5 30	−19 55			
			C.	−13 58	E.N.E.		− 5 30	−19 28			
		204 00	Cr.	−13 39	E.N.E.		− 5 30	−19 09			
12.	−60 18	212 00	C.	−12 51	E. by N.	−74 15	− 5 34	−18 25	+1 30	−17 19	
			C.	−12 57	E. by N.		− 5 34	−18 31			
			C.	−12 59	E. by N.		− 5 34	−18 33			
			C.	−11 39	E.N.E.		− 5 06	−16 45			
13.	−60 06	215 52	Cr.	−16 30	N.E.		− 3 43	−20 13			
14.	−59 12	219 18	Cr.	−16 01	N.E. by E.		− 4 29	−20 30			
15.	−58 50	222 00	C.	−12 10	E. by N.	−73 55	− 5 26	−17 36	+1 30	−16 03	
			C.	−13 06	E.N.E.		− 4 59	−18 05			
			C.	−10 27	E. by N.		− 5 26	−15 53			
			C.	−13 12	E. by N.		− 5 26	−18 38			
16.	−58 58	227 00	Cr.	−13 00	E. by S.	−73 05	− 5 31	−18 31	+1 30	−17 01	
18.	−60 18	236 30	C.	−18 40	E.	−73 00	− 5 24	−24 04	+1 30	−20 57	
			C.	−15 26	E.		− 5 24	−20 50			
			Cr.	−17 03	E.		− 5 24	−22 27			
19.	−60 02	240 31	Cr.	−17 53	E.N.E.	−72 15	− 4 25	−22 18	+1 30	−20 48	
22.	−58 28	251 40	C.	−18 33	E. by N.	−70 51	− 4 29	−23 02	+1 30	−22 46	
			Cr.	−20 01	E.		− 4 45	−24 46			
			Cr.	−19 58	E. by N.		− 4 29	−24 27			
			Cr.	−20 22	E. by N.		− 4 29	−24 51			
23.	−58 36	255 20	Cr.	−20 41	E. by N.	−70 11	− 4 18	−24 59	+1 30	−24 46	
			C.	−24 18	S.S.E.		− 2 07	−26 25			
			C.	−23 57	S.E. ½ E.		− 4 00	−27 57			
			C.	−24 13	E. by N.		− 4 18	−28 31			
			C.	−21 04	N.E. by E. ½ E.		− 3 41	−24 45			
			C.	−22 07	E. by N. ¼ N.		− 4 09	−26 16			
			C.	−20 43	E. by N.		− 4 18	−25 01			

Observations of Declination (Continued.)

1842.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Correction for index error.	True Declination.	Remarks.
	Lat.	Long.									
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	
Mar. 24.	−58 46	257 50	C.	−21 52	E. ¾ N.	−69 45	− 4 15	−26 07	+1 30	−26 13	
			C.	−24 59	E. by N.		− 4 11	−29 10			
			Cr.	−23 41	E. by N.		− 4 11	−27 52			
25.	−58 54	262 48	Cr.	−27 53	E.N.E.	−68 50	− 3 38	−31 31			
26.	−59 02	268 40	C.	−23 47	E.N.E.	−67 40	− 3 24	−27 11	+1 30	−26 25	
			C.	−24 43	E. by N. ¾ N.		− 3 29	−28 12			
			C.	−23 30	E. by N. ½ N.		− 3 34	−27 04			
			C.	−25 31	N.E. by E. ¾ E.		− 3 17	−28 48			
			Cr.	−22 22	E.N.E.		− 3 24	−25 46			
			Cr.	−25 51	N.E.		− 2 24	−28 15			
			Cr.	−22 29	E.		− 4 01	−26 30			
27.	−59 04	272 20	C.	−25 45	E.N.E.	−67 00	− 3 16	−29 01	+1 30	−27 08	
			C.	−26 39	E.N.E.		− 3 16	−29 55			
			Cr.	−25 53	E.N.E.		− 3 16	−29 09			
			Cr.	−23 12	E.N.E.		− 3 16	−26 28			
28.	−58 56	275 50	C.	−26 15	N.E. by E.	−65 30	− 2 35	−28 50	+1 30	−28 25	
			C.	−27 37	N.E. by E.		− 2 35	−30 12			
	−58 54	276 40	C.	−30 22	N. by E.		− 0 33	−30 55			
			C.	−29 25	N. by E.		− 0 33	−29 58			
			C.	−27 06	N.E. by E.		− 2 35	−29 41			
			C.	−27 54	N.E. by E.		− 2 35	−30 29			
			Cr.	−26 44	N.E. by E.		− 2 35	−29 19			
29.	−58 22	279 30	C.	−24 53	N.E. by E.	−64 50	− 2 30	−27 23	+1 30	−27 13	
			C.	−25 19	N.E. by E.		− 2 30	−27 49			
	−58 20	280 00	C.	−31 06	N. by W.		+ 0 31	−30 35			
			C.	−29 30	N. by E.		− 0 31	−30 01			
			C.	−24 59	E.		− 3 30	−28 29			
			C.	27 46	N.E. ½ E.		− 2 15	−30 01			
			C.	−25 09	E.N.E.		− 2 55	−28 04			
			C.	−25 27	E.N.E.		− 2 55	−28 22			
	−58 22	279 30	Cr.	−27 45	N.		0 0	−27 45			
			Cr.	−25 08	E.		− 3 30	−28 38			
30.	−58 30	282 00	C.	−24 51	N.E. by E. ½ E.	−63 40	− 2 35	−27 26	+1 30	−26 49	
			C.	−24 19	E.N.E.		− 2 47	−27 06			
			C.	−25 46	N.E. ½ E.		− 2 08	−27 54			
			C.	−25 46	N.E. by E.		− 2 23	−28 09			
			C.	−25 16	N.E. by E.		− 2 23	−27 39			
			C.	−25 49	N.E. by E.		− 2 23	−28 12			
			C.	−27 18	N.E. by E.		− 2 23	−29 41			
			C.	−25 46	N.E. by E.		− 2 23	−28 09			
			C.	−26 05	N.E. by E. ½ E.		− 2 35	−28 40			
			C.	−27 48	N.E. by E.		− 2 23	−30 11			
	−58 30	282 30	C.	−25 46	E. by N.	−63 00	− 3 02	−28 48	−1 30	−26 13	
			C.	−25 43	E. by N.		− 3 02	−28 45			
			Cr.	−25 04	E.N.E.		− 2 41	−27 45			
			Cr.	−25 25	E. by N.		− 3 02	−28 27			
			Cr.	−23 46	E.N.E.		− 2 41	−26 27			
31.	−58 26	285 08	C.	−26 49	N.E. by N.		− 1 23	−28 12			
			C.	−25 59	N.E. by N.		− 1 23	−27 22			
	−58 30	285 35	Cr.	−24 06	N.E.		− 1 50	−25 26			
April 1.	−57 35	288 54	Cr.	−25 30	N.E. by N.	−61 13	− 1 16	−26 46	+1 30	−25 16	
3.	−56 46	294 30	C.	−21 46	N.E.	−59 00	− 1 30	−23 16	+1 30	−20 26	
			Cr.	−19 07	N.E.		− 1 30	−20 37			
5.	−52 22	301 00	C.	−21 21	N. by E.	−53 54	− 0 17	−21 38	+1 30	−18 25	
			C.	−18 20	N. by E.		− 0 17	−18 38			
			C.	−20 32	N. by E.		− 0 17	−20 49			
6.	−51 50	301 35	C.	−19 07	N.N.W.	−52 30	+ 0 30	−18 37			

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
July 7.			Direct.	−70 16·1	S.E. ½ E.	−37	−6	−70 54	−70 54	Running out of Storm Bay.
			S.	−70 03·4	S.E. ½ E.	−37	−6			
			N.	−70 05·4	S.F. ½ E.	−37	−6			
			N.S.	−70 12·0	S.E. ½ E.	−37	−6			
			Direct.	−70 18·9	S.E. ½ E.	−37	−6			
8.	−43 00	148 28	Direct.	−71 27·3	N.N.E.	+78	−7	−70 25	−70 25	A heavy head sea.
			S.	−71 43·2	N.N.E.	+78	−7			
			N.	−71 36·7	N.N.E.	+78	−7			
			N.S.	−71 39·1	N.N.E.	+78	−7			
			Direct.	−71 32·2	N.N.E.	+78	−7			
9.	−42 13	149 25	Direct.	−70 46·5	N.N.W.	+77	−6	−69 37	−69 37	A head sea.
			S.	−70 56·3	N.N.W.	+77	−6			
			N.	−71 12 6	N.N.W.	+77	−7			
			N.S.	−70 30·2	N.N.W.	+77	−6			
			Direct.	−70 36·5	N.N.W.	+77	−6			
10.	−40 55	149 12	Direct.	−69 52·4	N. by W.	+76	−6	−68 41	−68 41	
			S.	−69 53·7	N. by W.	+76	−6			
			N.	−69 47·1	N. by W.	+76	−6			
			N.S.	−69 49·2	N. by W.	+76	−6			
11.	−37 50	150 22	Direct.	−67 47·8	N. by W.	+72	−5	−66 36	−66 36	
			N.	−67 53·9	N. by W.	+72	−5			
			N.S.	−67 28·9	N. by W.	+72	−5			
			Direct.	−67 40·4	N. by W.	+72	−5			
12.	−37 21	151 33	Direct.	−67 01·6	N.E.	+62	−4	−66 01	−66 01	
			S.	−66 58·0	N.E.	+62	−4			
			N.	−67 03·3	N.E.	+62	−4			
			N.S.	−66 49·4	N.E.	+62	−4			
			Direct.	−67 04·8	N.E.	+62	−4			
13.	−36 01	151 48	Direct.	−66 19·0	N.W. by N.	+64	−4	−65 04	−65 04	Much motion.
			N.	−65 57·0	N.W. by N.	+64	−4			
			N.S.	−65 52·9	N.W. by N.	+64	−4			
			Direct.	−66 08·5	N.W. by N.	+64	−4			
14.	−33 52	151 21	Direct.	−64 05·9	N.	+67	−3	−63 15	−62 47	Running along the land into Port Jackson.
			S.	−64 20·3	N.	+67	−3			
			N.	−64 05·4	N.	+67	−3			
			N.S.	−64 00·8	N.	+67	−3			
			Direct.	−65 03·8	N.	+67	−3			
14.	−33 51	151 20	Direct.	−63 49·0	N. by W.	+66	−3	−62 46		
			Direct.	−63 37·9	N.W.	+58	−3	−62 43		
			Direct.	−62 05·5	S.W. by W.	−17	−2	−62 25		
			Direct.	−62 03·1	S.E.	−35	−2	−62 40		
			Direct.	−61 52·5	S.S.W. ½ W.	−51	−2	−62 46		
31.			Direct.	−63 11·9	W.	+25	−2	−62 56		
	At anchor.		S.	−63 24·0	W.	+25	−3			
	−33 51	151 17	Direct.	−62 19·1	W.S.W.	− 2	−2	−62 23		
			Direct.	−61 12·6	S.	−63	−2	−62 24		
			S.	−61 26·1	S.	−63	−2			
			Direct.	−61 31·5	S.S.W.	−53	−2	−62 34		
			S.	−61 47·5	S.S.W.	−53	−2			
Aug. 3.			Direct.	−63 30·1	N.E.	+58	−3	−62 40		
			S.	−63 40·9	N.E.	+58	−3			

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Aug. 13.	−32° 12′	170° 27′	Direct.	−58° 47′·3	S.E. by E.	−12′	0′	−58° 33′	−58° 33′	Much motion.
			S.	−58 30·2	S.E. by E.	−12	0			
			N.	−58 09·7	S.E. by E.	−12	0			
			N.S.	−57 55·2	S.E. by E.	−12	0			
14.	−33 27	171 21	Direct.	−57 30·0	S.E. by E.	−12	+1	−58 24	−58 24	A head swell.
15.	−33 55	171 54	Direct.	−58 49·5	E. ½ S.	+20	0			
			S.	−59 03·7	E. ½ S.	+20	0			
			N.	−59 02·9	E. ½ S.	+20	0			
			N.S.	−58 59·8	E. ½ S.	+20	0			
			Direct.	−58 42·5	E. ½ S.	+20	0			
16.	−34 00	172 01	Direct.	−57 46·5	S.E. by E. ½ E.	− 4	+1			
16.	−34 21	178 48	Direct.	−58 49·3	E.S.E.	+ 4	0			
17.	−34 29	173 36	Direct.	−58 26·0	E.S.E.	+ 4	0	−58 26	−58 26	Much motion.
			S.	−58 42·5	E.S.E.	+ 4	0			
			N.	−58 02·7	E.S.E.	+ 4	0			
			N.S.	−58 42·0	E.S.E.	+ 4	0			
			Direct.	−58 17·0	E.S.E.	+ 4	0			
			Direct.	−58 50·8	E.S.E.	+ 4	0			
23.	Bay of Islands.		Direct.	−59 26·4	Observed on shore.	......	−1	−59 29	−59 29	
	−35 16	174 00	S.	−59 34·5						
			N.	−59 29·1						
			N.S.	−59 22·6						
			Direct.	−59 28·2*						
Oct. 27.			Direct.	−59 28 0†						
			S.	−59 43 2						
			N.	−59 31·9						
			N.S.	−59 26·2						
			Direct.	−59 28·3‡					−59 28	
20.	At anchor.		Direct.	−60 17·1	N.W. ½ N.	+54	−1	−59 49		
			S.	−61 03·1	N.W. ½ N.	+54	−1			
			Direct.	−58 31·7	S.	−57	0			
			S.	−59 05·6	S.	−57	0			
Nov. 23.	−35 15	174 39	Direct.	−59 25·0	E.S.E.	+1	−1	−59 25		Nov. 23, running along the land.
			Direct.	−59 37·7	E. by S.	+15	−1	−59 11		
			Direct.	−59 30·7	E. by S.	+15	−1			
			S.	−59 23·8	E. by S.	+15	−1			
			N.	−59 11·7	E. by S.	+15	−1			
			N.S.	−59 22·3	E. by S.	+15	−1			
24.	−36 27	177 34	Direct.	−59 50·0	E.S.E.	0	−1	−59 54	−59 54	
			Direct.	−59 56 2	E.S.E.	0	−1			
			S.	−59 48·2	E.S.E.	0	−1			
			N.	−59 48 2	E.S.E.	0	−1			
			N.S.	−60 03·2	E.S.E.	0	−1			
25.	−38 17	179 51	Direct.	−59 55·3	S.E. by S.	−34	−1	−60 32	−60 34	
			S.	−59 34·4	S.E. by S.	−34	−1			
			N.	−60 02·2	S.E. by S.	−34	−1			
			N.S.	−60 14·7	S.E. by S.	−34	−1			
			Direct.	−59 57·2	S.E. by S.	−34	−1			
			Direct.	−60 19·5	S.E.	−23	−1	−60 43		

* Observed on shore; face west.
Direct. −60° 33′·0
S. −60 30·1
N. −60 28·4
N.S. −60 19·6
Direct. −60 31·9

† Observed on shore; face west.
Direct. −60° 30′·1
S. −60 33·1
N. −60 40·4
N.S. −60 14·9
Direct. −60 32·0

‡ Observed on shore; face west.
Direct. −60° 29′·0
S. −60 28 8
N. −60 19·1
N.S. −60 18·9
Direct. −60 28·8
Nov. 13.

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Dec. 7.	−50° 48′	192° 20′	Direct.	−69° 18′·8	S.E. by E.	−21′	−6′	−69° 58′	−69° 43′	
			S.	−70 01·5	S.E. by E.	−21	−6			
			N.	−69 17·2	S.E. by E.	−21	−6			
			N.S.	−69 04·5	S.E. ½ E.	−26	−5	−69 42		
			Direct.	−69 17·0	S.E. ½ E.	−26	−6			
8.	−51 34	194 29	Direct.	−70 04·1	E. by S.	+ 6	−6	−70 10	−70 21	
			S.	−70 33·6	E. by S.	+ 6	−6			
			N.	−70 12·3	E. by S.	+ 6	−6			
			N.S.	−69 53·8	E. by S.	+ 6	−6			
			Direct.	−70 06·0	E. by S.	+ 6	−6			
9.	−52 02	197 53	Direct.	−70 19·0	E. by S.	+ 6	−6	−70 32		
			S.	−70 49·0	E. by S.	+ 6	−6			
			N.	−70 29·1	E. by S.	+ 6	−6			
			N.S.	−70 11·2	E. by S.	+ 6	−6			
			Direct.	−70 17·0	E. by S.	+ 6	−6			
			Direct.	−70 18·0	E. by S.	+ 6	−6			
10.	−53 01	202 11	Direct.	−71 08·0	E. ½ N.	+25	−6	−70 53	−70 44	Ship unsteady; much motion.
			S.	−71 26·2	E. ½ N.	+25	−7			
			N.	−71 13·0	E. ½ N.	+25	−7			
			N.S.	−71 09·7	E. ½ N.	+25	−6			
			Direct.	−71 05·0	E. ½ N.	+25	−6			
11.	−52 48	203 50	Direct.	−70 35·9	E.	+19	−6	−70 35		
			S.	−70 53·5	E.	+19	−6			
			N.	−70 54·6	E.	+19	−6			
			N.S.	−71 11·2	E.	+19	−6			
			Direct.	−70 30·4	E.	+19	−6			
12.	−53 01	205 08	Direct.	−69 56·8	E.S.E.	− 6	−6	−70 10	−70 10	
			S.	−70 11·6	E.S.E.	− 6	−6			
			N.	−70 00·7	E.S.E.	− 6	−6			
			N.S.	−69 42·3	E.S.E.	− 6	−6			
			Direct.	−69 56·5	E.S.E.	− 6	−6			
			Direct.	−70 01·5	E.S.E.	− 6	−6			
13.	−54 55	209 30	Direct.	−70 21·0	S.E. by E. ½ E.	−14	−6	−70 54	−70 58	
			S.	−70 55·7	S.E. by E. ½ E.	−14	−6			
			N.	−70 30·0	S.E. by E. ½ E.	−14	−6			
			N.S.	−70 44·5	S.E. by E. ½ E.	−14	−6			
			Direct.	−70 23·5	S.E. by E. ½ E.	−14	−6			
	−55 08	210 04	Direct.	−70 26·5	S.E. by E. ½ E.	−14	−6	−71 13		
			S.	−71 04·2	S.E. by E. ½ E.	−14	−6			
			N.	−70 34·7	S.E. by E. ½ E.	−14	−6			
			N.S.	−71 03·0	S.E. by E. ½ E.	−14	−6			
			Direct.	−70 27·5	S.E. by E. ½ E.	−14	−6			
	−55 20	210 28	Direct.	−70 35·5	S.E. by E. ½ E.	−15	−6	−71 11	−71 28	
			S.	−71 13·5	S.E. by E. ½ E.	−15	−7			
			N.	−70 48·7	S.E. by E. ½ E.	−15	−6			
			N.S.	−70 53·0	S.E. by E. ½ E.	−15	−6			
			Direct.	−70 39·0	S.E. by E. ½ E.	−15	−6			
14.	−56 20	211 52	Direct.	−70 38·0	S.E. by S.	−47	−6	−71 46		
			S	−71 23·9	S.E. by S.	−47	−7			
			N.	−71 01·3	S.E. by S.	−47	−6			
			N.S.	−70 36·2	S.E. by S.	−47	−6			
			Direct.	−70 43·0	S.E. by S.	−47	−6			

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Dec. 14.	−55 55	211 38	Direct.	−70 51·5	s.e. by s.	−48	− 6	−72 03	−72 18	
			S.	−71 59·2	s.e. by s.	−48	− 7			
			N.	−71 00·7	s.e. by s.	−48	− 6			
			N.S.	−71 04·0	s.e. by s.	−48	− 6			
			Direct.	−70 50·3	s.e. by s.	−48	− 6			
15.	−56 55	212 34	Direct.	−71 09·5	s.s.e.	−58	− 6	−72 33		
			S.	−72 36·0	s.s.e.	−58	− 7			
			N.	−71 18·2	s.s.e.	−58	− 7			
			N.S.	−71 14·5	s.s.e.	−58	− 7			
			Direct.	−71 07·5	s.s.e.	−58	− 6			
	−56 06	212 20	Direct.	−71 37·1	s.e. by s.	−48	− 7	−72 32	−72 08	
			Direct.	−71 48·0	e.s.e.	− 9	− 7	−72 03		
			S.	−72 14·8	e.s.e.	− 9	− 7			
			N.	−71 30·0	e.s.e.	− 9	− 7			
			N.S.	−71 31·0	e.s.e.	− 9	− 7			
			Direct.	−71 50·0	e.s.e.	− 9	− 7			
16.	−58 29	213 11	Direct.	−72 41·5	s.s.e.	−60	− 7	−73 40	−73 45	
			S.	−72 49·3	s.s.e.	−60	− 7			
			N.	−72 25·6	s.s.e.	−60	− 7			
			N.S.	−72 33·8	s.s.e.	−60	− 7			
			Direct.	−72 09·1	s.s.e.	−60	− 7			
	−58 36	213 17	Direct.	−72 38·0	s.s.e.	−60	− 7			
	−58 52	213 22	Direct.	−72 41·7	s.s.e.	−61	− 7	−73 52		
			S.	−72 47·0	s.s.e.	−61	− 7			
			N.	−72 40·0	s s.e.	−61	− 7			
			N.S.	−72 44·6	s.s.e.	−61	− 7			
			Direct.	−72 47·7	s.s.e.	−61	− 7			
17.	−61 03	213 57	Direct.	−74 02·5	s.s.e.	−62	− 8	−75 15	−75 32	
			S.	−74 27·7	s.s.e.	−62	− 8			
			N.	−73 50·0	s.s.e.	−62	− 8			
			N.S.	−73 58·7	s.s.e.	−62	− 8			
			Direct.	−74 04·6	s.s.e.	−62	− 8			
			Direct.	−74 08·0	s.s.e.	−62	− 8			
	−61 37	213 57	Direct.	−74 32·0	s. by e.	−69	− 8	−75 47		
			S.	−74 53·0	s. by e.	−69	− 8			
			N.	−74 07·0	s. by e.	−69	− 8			
			N.S.	−74 25·0	s. by e.	−69	− 8			
			Direct.	−74 33·0	s. by e.	−69	− 8			
18.	−62 40	212 53	Direct.	−75 01·5	s.	−72	− 8	−76 38	−76 36	
			S.	−75 20·3	s.	−72	− 9			
			N.	−75 10·5	s.	−72	− 8			
			N.S.	−75 47·0	s.	−72	− 9			
			Direct.	−75 07·8	s.	−72	− 8			
			Direct.	−75 10·0	s. by w.	−70	− 8	−76 32		
			Direct.	−75 18 0	s. by w.	−70	− 9			
19.	−63 23	210 02	Direct.	−76 17·0	s.s.w.	−63	− 9	−77 26	−77 26	
			S.	−76 23·3	s.s.w.	−63	− 9			
			N.	−75 54·0	s.s.w.	−63	− 9			
			N.S.	−76 24·0	s.s.w.	−63	− 9			
			Direct.	−76 12·6	s.s.w.	−63	− 9			
	−63 23	210 02	Direct.	−77 03·3	Observed on Ice.	....	− 9	−77 25	−77 25	
			S.	−77 45·7			−10			
			N.	−77 08·3			− 9			
			N.S.	−77 04·6*			− 9			

* Observed on ice; face west. } Direct. −78° 20′·3.

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections. Ship's attraction.	Corrections. Index.	True Inclination.	True Inclination.	Remarks.
Dec. 19.	−63° 23′	210° 02′	Direct.	−76° 48′·8	s.w. by w.	−28′	− 9′	−77° 26′	−77° 30′	
			Direct.	−77 02·5	w.s.w.	−13	− 9	−77 25		
			Direct.	−76 31·2	s.w. by s.	−55	− 9	−77 35		
20.	−63 47	208 26	Direct.	−76 26 6	s. by w.	−71	− 9	−77 58	−77 57	
			S.	−77 23·7	s. by w.	−71	−10			
			N.	−76 03·0	s. by w.	−71	− 9			
			N.S.	−76 36·6	s. by w.	−71	− 9			
			Direct.	−76 33·7	s.s.w.	−63	− 9	−77 46		
21.	−64 38	206 53	Direct.	−76 42·5	s.	−74	− 9	−78 32	−78 20	
			S.	−77 34·8	s.	−74	−10			
			N.	−76 39·4	s. by w.	−72	− 9	−78 09		
			N.S.	−76 49·5	s. by w.	−72	− 9			
			Direct.	−76 54·0	s. by w.	−72	− 9			
	−64 50	206 37	Direct.	−77 02·0	s. by E.	−72	− 9	−78 23		
			Direct.	−76 58·0	s.	−74	− 9	−78 21		
			Direct.	−77 13·3	s.s.w.	−64	−10	−78 27		
	−64 53	206 30	Direct.	−77 15·8	s. by w.	−72	−10	−78 55	−78 57	
			S.	−78 13·2	s. by w.	−72	−10			
			N.	−77 18·0	s. by w.	−72	−10			
			N.S.	−77 22·6	s. by w.	−72	−10			
			Direct.	−77 13·1	s.	−74	−10	−78 37		
22.	−65 30	205 41	Direct.	−77 37·4	s.	−75	−10	−79 06		
			Direct.	−77 37·4	s.	−75	−10			
			S.	−78 00·3	s.	−75	−10			
			N.	−77 47·2	s.	−75	−10			
			N.S.	−77 27·6	s.	−75	−10			
			Direct.	−77 38·0	s.	−75	−10			
23.	−65 59	204 16	Direct.	−79 50·3	E.N.E.	+40	−11	−79 53	−79 31	
			S.	−80 53·5	E.N.E.	+40	−11			
			Direct.	−78 04·0	s. by w.	−73	−10	−79 59		
			S.	−79 32·3	s. by w.	−73	−11			
			N.	−78 11·2	s. by w.	−73	−10			
			Direct.	−77 53·0	s.	−75	−10	−79 34		
			S.	−78 44·7	s.	−75	−10			Fast to a piece of ice.
			N.	−78 06·5	s.	−75	−10			
			N.S.	−77 51·8	s.	−75	−10			
24.	65 57	203 53	Direct.	−78 30·4	s.w. by w.	−30	−10	−79 10		
			Direct.	−80 25·6	N. by w.	+74	−11	−79 23		On the 24th lying becalmed alongside pieces of ice.
			Direct.	−80 11·7	N.E. by N.	+67	−11	−79 16		
			Direct.	−79 49·2	N.w. ½ w.	+57	−11	−79 03		
			Direct.	−80 27·2	N.	+76	−11	−79 22		
			Direct.	−80 01·6	N.w.	+60	−11	−79 13		
			Direct.	−79 16·6	w. by N.	+28	−11	−79 00		
			Direct.	−79 33·4	w.N.w.	+40	−11	−79 04		
	−65 58	203 51	Direct.	−78 14·3	s.s.w.	−65	−10	−79 29		
			S.	−79 34·4	s.w. by s.	−57	−11	−79 47		
			N.	−78 17·8	s.w. by s.	−57	−10			
			N.S.	−78 05·6	s.w. by s.	−57	−10			
			Direct.	−78 20·1	s.w.	−45	−10	−79 15		
25.	−66 00	203 46	Direct.	−79 38·5	E.	+14	−11	−80 08	−79 53	
			S.	−80 52·7	E.	+14	−11			
			N.	−79 46·8	E.	+14	−11			
			Direct.	−79 39·7	E.	+14	−11			
			Direct.	−80 29·6	N.w.	+60	−11	−79 54		
			Direct.	−79 45·6	E. by N.	+28	−11	−79 41		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Jan. 9.	−66 04	204 19	Direct.	−78 48·7	s.w. ½ w.	−37	−10	−79 36	−79 38	
			Direct.	−79 24·0	E. by s.	− 1	−11	−79 36		
			Direct.	−78 39·5	s.w.	−45	−10	−79 35		
10.	−65 59	204 12	Direct.	−78 50·8	s.w. by w.	−30	−10	−79 41		
			S.	−79 41·0	s.w. by w.	−30	−11			
			N.	−78 40·9	s.w. by w.	−30	−10			
			N.S.	−78 47·0	s.w. by w.	−30	−10			
			Direct.	−79 32·0	E.	+14	−11	−79 36		
			S.	−79 45·4	E.	+14	−11			
11.	−65 58	203 44	Direct.	−80 18·8	N.E. by E.	+55	−11	−79 35		
			Direct.	−78 19·8	s.	−75	−10	−79 45		
12.	−65 54	203 32	Direct.	−78 25·0	s.w.	−45	−10	−79 38		
			S.	−79 00·8	s.w.	−45	−10			
			Direct.	−78 26·9	s.w. ½ s.	−51	−10	−79 28		
13.	−66 11	203 03	Direct.	−79 08·0	s.w. ¾ w.	−34	−10	−79 52	−79 35	
			Direct.	−79 06·4	s.w. by w.	−30	−10	−79 46		
	−66 12	203 05	Direct.	−78 02·0	S.S.E.	−65	−10	−79 24		
			S.	−78 26·2	S.S.E.	−65	−10			
			N.	−78 00·7	S.S.E.	−65	−10			
			N.S.	−78 07·4	S.S.E.	−65	−10			
			Direct.	−80 37·5	N.N.E.	+72	−10	−79 43		
			S.	−80 51·9	N.N.E.	+72	−10			
			N.	−80 36·8	N.N.E.	+72	−11	−79 37	−79 33	
			N.S.	−80 40·1	N.N.E.	+72	−11			
			Direct.	−80 35·5	N.N.E.	+72	−11			
14.	−66 14	203 09	Direct.	−80 34·2	N.E. by E.	+55	−11	−79 50		
			Direct.	−78 00·9	s. by w.	−73	−10	−79 24		
			Direct.	−80 28·4	N.E.	+60	−11	−79 39		
			Direct.	−78 08·3	s. by w.	−73	−10	−79 31		
15.	−66 02	202 30	Direct.	−78 28·0	s.w.	−45	−10	−79 23		
16.	−65 49	202 02	Direct.	−79 21·4	E.	+14	−11	−79 18		
			S.	−79 28·9	Observed on ice.	....	−11	−79 47	−79 47	
			N.	−79 33·2			−11			
			N.S.	−79 58·8			−11			
			Direct.	−79 22·4*			−11			
19.	−66 18	201 22	Direct.	−79 08·3	s.w. by w.	−30	−10	−79 48	−80 01	
			Direct.	−81 06·4	N. by E.	+74	−11	−80 03		
21.	−66 49	202 40	Direct.	−78 33·0	s. by E.	−73	−10	−80 05		
			S.	−79 08·5	s. by E.	−73	−10			
			N.	−78 35·4	s. by E.	−73	−10			
			N.S.	−78 29·5	s. by E.	−73	−10			
28.	−67 38	204 01	Direct.	−81 23·9	N.	+76	−12	−80 30	−80 22	
			N.	−81 37·4	N.	+76	−12			
			S.	−81 39·4	N.	+76	−12			
			Direct.	−78 53·5	s.	−75	−10	−80 19		
			Direct.	−79 00·5	s. by w. ½ w.	−69	−10	−80 20		
29.	−67 32	203 59	Direct.	−79 00·4	S.S.W.	−65	−10	−80 17		
			S.	−79 04·6	S.S.W.	−65	−10			
			N.	−79 01·8	S.S.W.	−65	−10			
			N.S.	−79 01·9	S.S.W.	−65	−10			

* Observed on ice, face west } Direct. −80° 39′·2.

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Jan. 30.	−67 18	203 39	Direct.	−79 30·8	s.w. ½ s.	−51	−11			
			S.	−80 28·3	s.w. ½ s.	−51	−11	−80 47		
			N.	−79 38·7	s.w. ½ s.	−51	−11			
			N.S.	−79 25·5	s.w. ½ s.	−51	−11			
			Direct.	−79 59·3	s. by w.	−73	−10	−81 22		
31.	−67 21	202 15	Direct.	−79 04·4	s.w.	−45	−10		−80 26	
			S.	−79 19·5	s.w.	−45	−11	−80 02		
			N.	−79 04·2	s.w.	−45	−10			
			N.S.	−79 00·3	s.w.	−45	−10			
			Direct.	−79 39·1	w.s.w.	−15	−11	−80 09		
Feb. 1.	−67 11	202 07	Direct.	−79 48·5	w.s.w.	−15	−11			
2.	−67 57	200 00	Direct.	−79 22·4	s.e.	−45	−11	−80 18		
			Direct.	−79 59·5	s. by w.	−73	−11	−81 24		
			Direct.	−79 32·0	s.s.e. ½ e.	−61	−11		−80 46	
			S.	−79 49·7	s.s.e. ½ e.	−61	−11			
			N.	−79 30·2	s.s.e. ½ e.	−61	−11	−80 44		
			N.S.	−79 23·0	s.s.e. ½ e.	−61	−11			
			Direct.	−79 27·3	s.s.e. ½ e.	−61	−11			
3.	−68 21	200 03	Direct.	−80 01·0	s.e. by s.	−57	−11			
			S.	−79 53·0	s.e. by s.	−57	−11			
			N.	−79 50·4	s.e. by s.	−57	−11	−81 04		Much motion.
			N.S.	−79 57·1	s.e. by s.	−57	−11			
			Direct.	−79 56·8	s.e. by s.	−57	−11			
4.	−68 42	199 44	Direct.	−79 58·7	s. ½ e.	−74	−11			
			S.	−80 17·9	s. ½ e.	−74	−11		−81 14	
			N.	−79 57·9	s. ½ e.	−74	−11	−81 24		
			N.S.	−79 41·9	s. ½ e.	−74	−11			
			Direct.	−79 59·2	s. ½ e.	−74	−11			
	−68 49	199 41	Direct.	−82 12·8	n. by w.	+74	−12	−81 09		
5.	−68 59	196 07	Direct.	−80 53·5	s.w.	−45	−11	−81 00		
		195 51	Direct.	−80 49·0	s.w. by s.	−57	−11			
			S.	−81 02·2	s.w. by s.	−57	−11	−81 57	−81 54	
			N.	−80 46·0	s.w. by s.	−57	−11			
			N.S.	−80 39·6	s.w. by s.	−57	−11			
			Direct.	−81 52·8	w. ½ n.	+22	−12	−81 43		
6.	−69 48	192 25	Direct.	−81 08·5	s. by w.	−74	−11			
			S.	−81 28·9	s. by w.	−74	−12			
			N.	−81 11·0	s. by w.	−74	−11	−82 35	−82 35	
			N.S.	−80 47·4	s. by w.	−74	−11			
			Direct.	−81 12·3	s. by w.	−74	−12			
7.	−70 05	191 10	Direct.	−81 45·1	s.w.	−46	−12	−82 43		
			S.	−81 50·1	s.s.w.	−66	−12		−82 51	Much motion.
			N.	−81 38·8	s.s.w.	−66	−12			
			N.S.	−81 13·2	s.s.w.	−66	−12	−82 53		
			Direct.	−81 29·8	s.s.w.	−66	−12			
	−70 17	190 15	Direct.	−81 43·0	s.s.w.	−66	−12			
	−70 26	189 00	Direct.	−82 07·0	s.s.w.	−66	−12			
			S.	−81 39·2	s.s.w.	−66	−12			
			N.	−81 44·5	s.s.w.	−66	−12	−83 07	−83 07	Much motion.
			N.S.	−81 27·0	s.s.w.	−66	−12			
			Direct.	−82 10·2	s.s.w.	−66	−12			
8.	−70 18	186 01	Direct.	−81 50·6	s.	−77	−12			
			S.	−81 59·7	s.	−77	−12			
			N.	−81 49·3	s.	−77	−12	−83 18	−83 18	
			N.S.	−81 37·1	s.	−77	−12			
			Direct.	−81 50·0	s.	−77	−12			

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Feb. 9.	−70 39	185 31	Direct.	−82 06·3	S. by E.	−75	−12	−83 33	−83 35	
			Direct.	−82 24·5	S.E. by S.	−58	−12	−83 36		
			S.	−82 50·4	S.E. by S.	−58	−12			
			N.	−82 14·6	S.E. by S.	−58	−12			
			N.S.	−82 17·0	S.E. by S.	−58	−12			
			Direct.	−82 23·2	S.E. by S.	−58	−12			
10.	−70 11	183 50	Direct.	−83 23·9	W. by S.	0	−13	−83 33	−83 33	A head swell.
			S.	−83 21·9	W. by S.	0	−13			
			N.	−83 17·2	W. by S.	0	−13			
			N.S.	−83 17·1	W. by S.	0	−13			
			Direct.	−83 21·9	W. by S.	0	−13			
	−70 04	183 36	Direct.	−83 25·0*	S. by W.	−75	−13	−84 53		A head swell.
11.	−70 06	181 50	Direct.	−82 47·0	S.W. by S.	−58	−12	−83 57	−84 06	A heavy cross sea.
	−70 10	181 34	Direct.	−82 58·5	S.W.	−47	−12	−83 49		
			N.	−83 07·2	S.W.	−47	−12			
			N.S.	−82 25·0	S.W.	−47	−12			
12.	−71 00	180 44	Direct.	−83 01·3	S.E. by S.	−58	−12	−84 18		
			S.	−83 03·7	S.E. by S.	−58	−12			
			N.	−83 18·7	S.E. by S.	−58	−13			
			N.S.	−83 12·7	S.E. by S.	−58	−13			
			Direct.	−83 05·5	S.E. by S.	−58	−12			
13.	−72 46	181 46	Direct.	−83 32·6	S.E. by S.	−59	−13	−85 01	−85 04	
			S.	−84 23·9	S.E. by S.	−59	−13			
			N.	−83 46·0	S.E. by S.	−59	−13			
			N.S.	−83 45·2	S.E. by S.	−59	−13			
			Direct.	−83 36·7	S.E. by S.	−59	−13			
			Direct.	−84 04·8	S.E.	−47	−13	−85 05		
14.	−73 23	183 04	Direct.	−84 36·5	S.E. ½ S.	−53	−13	−85 42	−86 02	Very much motion.
15.	−74 24	177 09	Direct.	−85 07·0	S.S.E. ½ E.	−63	−13	−86 23		
16.	−74 56	173 36	Direct.	−85 17·0	S.S.E.	−69	−14	−86 48	−86 52	Very unsteady.
			S.	−85 51·8	S.S.E.	−69	−14			
			N.	−85 20·5	S.S.E.	−69	−14			
			N.S.	−85 10·0	S.S.E.	−69	−13			
			Direct.	−85 21·0	S. by E. ½ E.	−74	−14	−86 49		
			Direct.	−86 03·6	S.E.	−48	−14	−87 06		
	−75 10	173 08	Direct.	−86 46·9	E.	+16	−14	−86 59	−86 59	
			S.	−87 28·5	E.	+16	−15			
			N.	−87 06·9	E.	+16	−14			
			N.S.	−86 56·4	E.	+16	−14			
			Direct.	−86 48·5	E.	+16	−14			
17.	−75 53	175 05	Direct.	−87 01·5	E.N.E.	+42	−14	−86 44	−86 44	
	−76 00	175 15	Direct.	−87 03·5	E.N.E.	+42	−14			
			S.	−87 29·1	E.N.E.	+42	−15			
			N.	−87 26·9	E.N.E.	+42	−15			
			N.S.	−87 06·3	E.N.E.	+42	−14			
			Direct.	−87 07·0	E.N.E.	+42	−14			
18.	−76 58	181 03	Direct.	−86 58·5	E.N.E.	+42	−14	−86 46	−86 46	
			S.	−87 17·7	E.N.E.	+42	−15			
			N.	−87 37·8	E.N.E.	+42	−15			
			N.S.	−87 18·8	E.N.E.	+42	−15			
			Direct.	−86 57·8	E.N.E.	+42	−14			

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* This observation differs so widely from the others made on the same day, that, considering the unfavourable state of the weather, I have omitted it in the mean results: possibly the ship's head may have been W. by S. instead of S. by W., in which case the observation would agree well with the others.—E. S.

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Feb. 19.	−76 42	184 09	Direct.	−87 24·5	N. by E.	+78	−15	−86 07	−86 07	Ship pitching.
			S.	−86 57·7	N. by E.	+78	−14			
			N.	−87 15·6	N. by E.	+78	−15			
			N.S.	−86 56·5	N. by E.	+78	−14			
			Direct.	−87 21·2	N. by E.	+78	−15			
	−76 46	186 15	Direct.	−87 08·0	N.N.E.	+75	−14	−86 07		
20.	−76 14	192 35	Direct.	−85 58·3	N.E. ½ E.	+60	−14	−85 12	−85 18	A head sea and much motion.
21.	−75 53	194 52	Direct.	−84 24·3	S.W.	−47	−13	−85 24		
22.	−76 42	194 48	Direct.	−84 03·9	S.E. by S.	−60	−13	−85 25	−85 25	A swell from the southward.
			S.	−84 19·6	S.E. by S.	−60	−13			
			N.	−84 24·0	S.E. by S.	−60	−13			
			N.S.	−84 10·5	S.E. by S.	−60	−13			
			Direct.	−84 04·0	S.E. by S.	−60	−13			
	−76 42	194 10	Direct.	−84 56·5	E.S.E.	−17	−13	−85 26		
	−77 05	194 38	Direct.	−84 53·0	E. by S.	0	−13	−85 24	−85 24	
			S.	−85 36·6	E. by S.	0	−14			
			N.	−85 16·0	E. by S.	0	−14			
			N.S.	−85 13·0	E. by S.	0	−14			
			Direct.	−84 55·0	E. by S.	0	−13			
23.	−77 49	197 24	Direct.	−84 26·5	E. by S.	0	−13	−84 40	−84 49	
			Direct.	−84 05·3	S.W. by W.	−33	−13	−84 51		
	−78 07	197 44	Direct.	−84 40·3	E. ½ S.	+ 8	−13	−84 45		
	−78 07	197 46	Direct.	−84 51·9	W. by N.	+30	−13	−84 35		
24.	−76 55	198 40	Direct.	−84 12·0	S.W.	−47	−13	−85 12		
25.	−74 50	193 45	Direct.	−84 41·0	W.	+15	−13	−84 53	−84 49	
			S.	−84 57·7	W.	+15	−13			
			N.	−85 13·0	W.	+15	−14			
			N.S.	−84 50·0	W.	+15	−13			
			Direct.	−84 50·3	W. by N.	+30	−13	−84 33		
			Direct.	−83 27·2	S.S.W.	−68	−13	−84 48		
26.	−72 46	189 59	Direct.	−85 15·7	N.W. by W.	+57	−14	−84 38	−84 38	
			S.	−85 38·0	N.W. by W.	+57	−14			
			N.	−85 14·5	N.W. by W.	+57	−14			
			N.S.	−85 25·5	N.W. by W.	+57	−14			
			Direct.	−85 11·3	N.W. by W.	+57	−13			
27.	−72 01	187 35	Direct.	−83 38·0	W.S.W.	−16	−13	−84 10	−84 10	
			S.	−83 48·2	W.S.W.	−16	−13			
			N.	−83 44·1	W.S.W.	−16	−13			
			N.S.	−83 44·2	W.S.W.	−16	−13			
			Direct.	−83 40·8	W.S.W.	−16	−13			
28.	−71 08	184 59	Direct.	−84 05·5	W.	+15	−13	−84 04	−84 04	
			S.	−84 18·4	W.	+15	−13			
			N.	−84 06·5	W.	+15	−13			
			N.S.	−84 10·4	W.	+15	−13			
			Direct.	−84 04·5	W.	+15	−13			
			Direct.	−83 48·6	W.	+15	−13			
Mar. 1.	−69 52	180 04	Direct.	−84 35·5	W. by N.	+33	−13	−83 34	−83 34	
			S.	−83 59·2	W. by N.	+33	−13			
			N.	−83 45·0	W. by N.	+33	−13			
			N.S.	−83 39·7	W. by N.	+33	−13			
			Direct.	−83 32·0	W. by N.	+33	−13			
	−69 44	179 53	Direct.	−84 59·1	N. by E.	+93	−13	−83 31	−83 31	A northerly swell.
			S.	−84 36·6	N. by E.	+93	−13			
			N.	−84 54·2	N. by E.	+93	−13			
			N.S.	−84 52·0	N. by E.	+93	−13			
			Direct.	−84 54·0	N. by E.	+93	−13			

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Mar. 2.	−68 04	183 25	Direct.	−83 43·3	N.N.E.	+90	−13	−82 28	−82 13	
			S.	−83 54·0	N.N.E.	+90	−13			
			N.	−83 50·2	N.N.E.	+90	−13			
			N.S.	−83 38·2	N.N.E.	+90	−13			
			Direct.	−83 37·5	N.N.E.	+90	−13			
			Direct.	−83 03·2	N.E. by N.	+82	−12	−81 57		
			S.	−83 14·4	N.E. by N.	+82	−13			
			N.	−83 12·7	N.E. by N.	+82	−13			
			N.S.	−83 04·7	N.E. by N.	+82	−12			
			Direct.	−82 59·0	N.E. by N.	+82	−12			
3.	−67 32	185 09	Direct.	−82 31·0	E.N.E.	+51	−12	−81 56	−81 51	
			S.	−82 41·5	E.N.E.	+51	−12			
			N.	−82 44·3	E.N.E.	+51	−12			
			N.S.	−82 23·6	E.N.E.	+51	−12			
			Direct.	−82 48·7	N.E. by N.	+81	−12	−81 40		
	−67 28	185 33	Direct.	−82 34·8	N.E.	+74	−12	−81 33		
4.	−67 29	188 11	Direct.	−80 39·5	W.S.W.	−20	−11	−81 11	−81 02	A very heavy sea and much motion.
5.	−67 16	188 10	Direct.	−82 05·6	N. by E.	+91	−12	−80 59		A very heavy swell from the westward.
			N.	−82 37·2	N. by E.	+91	−12			
			N.S.	−82 29·0	N. by E.	+91	−12			
			Direct.	−81 59·0	N. by E.	+91	−12			
6.	−65 25	191 48	Direct.	−80 28·3	N. by E.	+89	−11	−79 19	−79 19	Much motion.
			N.	−80 41·9	N. by E.	+89	−11			
			N.S.	−80 54·6	N. by E.	+89	−11			
			Direct.	−80 31·8	N. by E.	+89	−11			
	−65 06	192 21	Direct.	−80 24·0	N. by E.	+89	−11			
7.	−63 30	194 22	Direct.	−79 37·0	N. by E.	+88	−11	−78 11	−78 11	
			Direct.	−79 31·3	N. by E.	+88	−11			
			S.	−79 44·5	N. by E.	+88	−11			
			N.	−79 08·1	N. by E.	+88	−10			
			N.S.	−79 20·2	N. by E.	+88	−11			
			Direct.	−79 27·4	N. by E.	+88	−11			
8.	−62 16	196 10	Direct.	−78 35·1	N. by E.	+87	−10	−77 17	−77 17	
			S.	−78 40·4	N. by E.	+87	−10			
			N.	−78 30·5	N. by E.	+87	−10			
			N.S.	−78 34·0	N. by E.	+87	−10			
			Direct.	−78 31·9	N. by E.	+87	−10			
9.	−61 14	198 38	Direct.	−77 33·0	N.E. by N.	+76	−10	−76 34	−76 34	
			S.	−78 15·5	N.E. by N.	+76	−10			
			N.	−77 36·7	N.E. by N.	+76	−10			
			N.S.	−77 24·7	N.E. by N.	+76	−10			
	−60 58	199 11	Direct.	−77 23·8	N.E. by N.	+76	−10			
	−60 50	200 11	Direct.	−76 36·5	N.E. by N.	+75	− 9	−75 33	−75 33	
			S.	−77 19·5	N.E. by N.	+75	−10			
			N.	−76 31·7	N.E. by N.	+75	− 9			
			N.S.	−76 09·5	N.E. by N.	+75	− 9			
			Direct.	−76 34·0	N.E. by N.	+75	− 9			
10.	−60 18	203 55	Direct.	−75 33·0	E.N.E.	+48	− 9	−74 54	−75 08	A cross sea, ship pitching.
	−60 18	204 11	Direct.	−75 23·0	E. by N.	+33	− 9	−75 11		
			S.	−76 07·5	E. by N.	+33	− 9			
			N.	−76 18·0	E. by N.	+33	− 9			
			N.S.	−75 48·2	E. by N.	+33	− 9			
			Direct.	−75 24·4	E. by N.	+33	− 9			
11.	−60 18	208 29	Direct.	−74 27·0	E. by N.	+33	− 9			Very much motion.

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Mar. 12.	−60 13	211 34	Direct.	−74 06·5	E. by N.	+33	−8	−74 21	−74 21	A heavy swell, ship very unsteady.
			S.	−74 23·3	E. by N.	+33	−8			
			N.	−74 57·0	E. by N.	+33	−8			
			N.S.	−74 57·5	E. by N.	+33	−8			
			Direct.	−74 18·0	E. by N.	+33	−8			
	−60 12	212 32	Direct.	−74 02·5	E. by N.	+33	−8			
13.	−60 00	216 12	Direct.	−73 56·0	N.E.	+67	−8	−72 57	−73 30	Very unsteady.
14.	−59 24	218 58	Direct.	−73 26·6	N.E. by E.	+59	−8	−73 13		
			S.	−74 20·7	N.E. by E.	+59	−8			
			N.	−73 57·5	N.E. by E.	+59	−8			
			N.S.	−73 47·2	N.E. by E.	+59	−8			
			Direct.	−73 35·3	N.E. by E.	+59	−8			
			Direct.	−75 17·5	N.E. by E.	+59	−9			
	−59 16	219 30	Direct.	−75 10·5	N.E. by E.	+59	−8	−74 03		
			S.	−74 54·1	N.E. by E.	+59	−8			
			N.	−74 42·7	N.E. by E.	+59	−8			
			N.S.	−74 49·5	N.E. by E.	+59	−8			
15.	−58 54	222 04	Direct.	−74 32·1	E.N.E.	+48	−8	−73 41	−73 38	
			S.	−74 07·2	E.N.E.	+48	−8			
			N.	−74 26·1	E.N.E.	+48	−8			
			N.S.	−74 11·7	E.N.E.	+48	−8			
			Direct.	−74 28·8	E.N.E.	+48	−8			
	−58 50	223 24	Direct.	−73 57·5	E. by N.	+33	−8	−73 31		
			Direct.	−73 55·0	E. by N.	+33	−8			
16	−59 00	227 32	Direct.	−73 11·8	E.	+19	−7	−72 57	−72 57	
			Direct.	−73 11·0	E.	+19	−7			
	−59 04	228 57	S.	−72 20·2	E.	+19	−7			
			N.	−73 06·0	E.	+19	−7			
			N.S.	−73 54·2	E.	+19	−8			
			Direct.	−73 14·5	E.	+19	−8			
			Direct.	−73 07·3	E.	+19	−7			
17.	−59 39	232 48	Direct.	−72 45·0	E. ½ S.	+12	−7	−72 54	−72 54	A great deal of motion.
			S.	−72 57·6	E. ½ S.	+12	−7			
			N.	−73 23·0	E. ½ S.	+12	−7			
			N.S.	−73 10·7	E. ½ S.	+12	−7			
			Direct.	−72 39·0	E. ½ S.	+12	−7			
	−59 45	233 53	Direct.	−72 24·5	E. ½ S.	+12	−7	−72 51	−72 51	A great deal of motion.
			S.	−73 00·5	E. ½ S.	+12	−7			
			N.	−73 16·7	E. ½ S.	+12	−7			
			N.S.	−73 03·0	E. ½ S.	+12	−7			
18.	−60 16	236 11	Direct.	−72 35·5	E. by S.	+ 4	−7	−73 00	−70 00	Ship unsteady.
			S.	−73 02·2	E. by S.	+ 4	−7			
			N.	−73 21·7	E. by S.	+ 4	−8			
			N.S.	−72 57·0	E. by S.	+ 4	−7			
			S.	−73 04·2	E.	+19	−7			
	−60 21	237 02	Direct.	−72 29·8	E.	+19	−7	−72 45	−72 45	Ship rolling deeply.
			S.	−73 16·5	E.	+19	−8			
			N.	−73 25·6	E.	+19	−8			
			N.S.	−73 01·3	E.	+19	−7			
			Direct.	−72 33·0	E.	+19	−7			
	−60 20	237 50	Direct.	−72 57·5	E. by N.	+33	−7	−72 56	−72 44	
			S.	−73 24·1	E. by N.	+33	−8			
			N.	−73 44·0	E. by N.	+33	−8			
			N.S.	−73 19·0	E. by N.	+33	−8			

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Mar. 18.	−60 20	237 50	Direct.	−73 15·0	E. by N. ½ N.	+40	−8	−72 34	−72 44	
	−60 19	238 00	Direct.	−72 24·5	E. by N. ½ N.	+40	−7			
			S.	−72 55·7	E. by N. ½ N.	+40	−7			
			N.	−73 24·6	E. by N. ½ N.	+40	−8			
			N.S.	−73 30·6	E. by N. ½ N.	+40	−8			
19.	−60 02	241 03	Direct.	−72 52·5	E.N.E.	+47	−7	−72 40	−72 40	Much motion.
	−60 01	241 38	Direct.	−72 45·5	E.N.E.	+47	−7			
			S.	−73 47·5	E.N.E.	+47	−8			
			N.	−73 43·0	E.N.E.	+47	−8			
			N.S.	−73 28·0	E.N.E.	+47	−8			
20.	−59 17	245 40	Direct.	−72 08·0	E.N.E.	+47	−7	−71 29	−71 29	
			S.	−72 12·0	E.N.E.	+47	−7			
			N.	−72 01·0	E.N.E.	+47	−7			
			N.S.	−72 14·0	E.N.E.	+47	−7			
			Direct.	−72 09·5	E.N.E.	+47	−7			
21.	−59 15	248 12	Direct.	−71 33·5	E. by N.	+33	−7	−71 26	−71 26	
			S.	−72 10·0	E. by N.	+33	−7			
			N.	−71 55·9	E. by N.	+33	−7			
			N.S.	−72 11·2	E. by N.	+33	−7			
			Direct.	−71 35·2	E. by N.	+33	−7			
	−59 04	248 50	Direct.	−71 53·5	N.E. ½ E.	+61	−7	−70 59	−71 04	
	−58 58	249 24	Direct.	−71 46·0	N.E. by E.	+58	−7	−71 08		
			S.	−72 01·2	N.E. by E.	+58	−7			
			N.	−71 53·0	N.E. by E.	+58	−7			
			N.S.	−72 14·7	N.E. by E.	+58	−7			
			Direct.	−71 30·6	E.N.E.	+47	−7	−70 51		
22.	−58 28	252 01	Direct.	−71 11·0	E. by N.	+33	−6	−70 44	−70 50	A head sea.
	−58 29	252 22	Direct.	−71 02·4	E. ½ N.	+26	−6	−70 52		
			S.	−71 33·5	E. ½ N.	+26	−7			
			N.	−71 05·8	E. ½ N.	+26	−6			
			N.S.	−71 07·4	E. ½ N.	+26	−6			
23.	−58 35	255 10	Direct.	−70 26·0	E. ½ N.	+26	−6	−70 11	−70 11	
			S.	−70 36·9	E. ½ N.	+26	−6			
			N.	−70 45·2	E. ½ N.	+26	−6			
			N.S.	−70 16·0	E. ½ N.	+26	−6			
			Direct.	−70 30·0	E. ½ N.	+26	−6			
24.	−58 44	257 49	Direct.	−70 04·5	E. ½ N.	+26	−6	−69 47	−69 47	
			S.	−70 29·6	E. ½ N.	+26	−6			
			N.	−70 24·7	E. ½ N.	+26	−6			
			N.S.	−69 49·2	E. ½ N.	+26	−6			
	−58 51	258 34	Direct.	−69 48·3	E. ½ N.	+26	−6			
25.	−58 56	263 52	Direct.	−68 52·8	E. by N. ½ N.	+40	−5	−67 39	−67 39	A heavy swell.
26.	−59 01	267 59	Direct.	−67 56·0	E. by N. ½ N.	+40	−5			
			S.	−68 21·7	E. by N. ½ N.	+40	−5			
			N.	−68 18·7	E. by N. ½ N.	+40	−5			
			N.S.	−67 56·8	E. by N. ½ N.	+40	−5			
			Direct.	−67 59·5	E. by N. ½ N.	+40	−5			
27.	−59 02	271 58	Direct.	−67 25·5	E.N.E.	+46	−5	−67 01	−67 01	Ship unsteady.
			S.	−68 44·6	F.N.E.	+46	−5			
			N.	−67 35·7	E.N.E.	+46	−5			
			N.S.	−67 13·7	E.N.E.	+46	−5			
			Direct.	−67 30·5	E.N.E.	+46	−5			

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Mar. 28.	−58° 55′	276° 30′	Direct.	−66° 10′·0	N.E. by E.	+55′	−4′	−65° 27′	−65° 27′	
	−58 50	277 12	Direct.	−66 13·0	N.E. by E.	+55	−4			
			S.	−66 41·4	N.E. by E.	+55	−4			
			N.	−66 22·2	N.E. by E.	+55	−4			
			N.S.	−66 14·5	N.E. by E.	+55	−4			
			Direct.	−66 09·5	N.E. by E.	+55	−4			
29.	−58 23	280 03	Direct.	−65 40·5	N.E. ½ E.	+57	−4	−64 49	−64 49	
			S.	−65 56·7	N.E. ½ E.	+57	−4			
			N.	−65 46·0	N.E. ½ E.	+57	−4			
			N.S.	−65 28·5	N.E. ½ E.	+57	−4			
			Direct.	−65 36·0	N.E. ½ E.	+57	−4			
30.	−58 29	282 04	Direct.	−64 27·9	N.E. by E. ½ E.	+50	−3	−63 44	−63 41	
			S.	−64 27·7	N.E. by E. ½ E.	+50	−3			
			N.	−64 39·2	N.E. by E. ½ E.	+50	−3			
			N.S.	−64 29·9	N.E. by E. ½ E.	+50	−3			
	−58 28	282 32	Direct.	−64 22·0	N.E. ½ E.	+54	−3	−63 31		
31.	−58 34	285 44	Direct.	−63 52·3	N.E. ½ N.	+58	−3	−62 57	−63 05	A very heavy swell.
			Direct.	−63 49 0	N.E. by N.	+60	−3	−63 7		
	−58 29	286 04	N.	−64 34·2	N.E. by N.	+60	−3			
			N.S.	−64 10·0	N.E. by N.	+60	−3			
			Direct.	−63 43·0	N.E. by N.	+60	−3			
April 1.	−57 22	289 50	Direct.	−62 24·0	N.E. by N.	+56	−2	−61 15	−61 15	
			S.	−62 16·2	N.E. by N.	+56	−2			
			N.	−61 50·6	N.E. by N.	+56	−2			
			N.S.	−61 59·0	N.E. by N.	+56	−2			
			Direct.	−62 17·0	N.E. by N.	+56	−2			
2.	−57 10	292 11	Direct.	−59 31·0	E.N.E.	+44	−1	−58 45	−58 51	A swell from the westward.
			S.	−59 28·3	E.N.E.	+44	−1			
			N.	−59 55·5	E.N.E.	+44	−1			
			N.S.	−58 59·0	E.N.E.	+44	0			
			Direct.	−59 25·3	E.N.E.	+44	−1			
	−57 17	292 32	Direct.	−58 35·5	S.S.E.	−46	0	−59 21		
3.	−56 40	294 46	Direct.	−59 44·0	N.E.	+55	−1	−59 01	−59 01	
			S.	−60 36·7	N.E.	+55	−1			
			N.	−60 05·7	N.E.	+55	−1			
			N.S.	−59 36·5	N.E.	+55	−1			
			Direct.	−59 33·5	N.E.	+55	−1			
4.	−54 50	298 08	Direct.	−57 34·0	N. by E.	+54	0	−56 10	−56 10	Too much motion to use S.
			N.	−57 00·3	N. by E.	+54	0			
			N.S.	−57 10·0	N. by E.	+54	0			
			Direct.	−57 24·0	N. by E.	+54	0			
5.	−52 54	300 27	Direct.	−54 47·5	N.N.E.	+47	+2	−53 52	−53 52	
			S.	−54 56·6	N.N.E.	+47	+2			
			N.	−54 45·7	N.N.E.	+47	+2			
			N.S.	−54 30·7	N.N.E.	+47	+2			
			Direct.	−54 26·0	N.N E.	+47	+2			
6.	−52 36	301 18	Direct.	−54 23·8	N.N.E.	+41	+2	−53 41	−52 34	
	−51 47	302 15	Direct.	−53 08·0	N.W. by N.	+42	+3	−52 23		
			Direct.	−52 10·0	E. by S.	+18	+3	−51 39		
11.	Port Louis, Falkland Islands.		Direct.	−52 29·1	Observed on shore.	..	+3	−52 30	−52 30	
			S.	−52 42·7						
	−51 32	301 53	N.	−52 37·9						
			N.S.	−52 41·2*						

* Observed on shore; face west.
- Direct. −53° 48′·9
- S. −53 29·2
- N. −53 45·9
- N.S. −53 41·5

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method. employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Aug. 19.	−51° 32′	301° 53′	Direct.	−52° 20′·6	Observed on shore.	. . ′	+3′	−52° 30′	−52° 30′	
			S.	−52 35·6						
			N.	−52 24·4						
			N.S.	−52 31·5*						
17.	−51 32	301 53	Direct.	−52 46·5	W.	+37	+3	−52 14	−52 05	
		To obtain corrections for the ship's attraction.	S.	−53 00·9	W.	+37	+3			
			Direct.	−52 38·8	W.N.W.	+38	+3	−51 58		
			S.	−52 39·4	W.N.W.	+38	+3			
	At Anchor.		Direct.	−52 45·8	N.W.	+42	+3	−52 08		
			S.	−52 59·5	N.W.	+42	+3			
			Direct.	−52 53·0	N.N.W.	+41	+3	−52 06		
			S.	−52 46·4	N.N.W.	+41	+3			
			Direct.	−52 54·0	N.	+41	+3	−52 09		
			S.	−52 52·3	N.	+41	+3			
			Direct.	−52 37·5	N.N.E.	+41	+3	−51 57		
			S.	−52 44·0	N.N.E.	+41	+3			
			Direct.	−52 42·5	N.E.	+42	+3	−51 58		
			S.	−52 43·2	N.E.	+42	+3			
			Direct.	−52 42·2	E.N.E.	+38	+3	−52 02		
			S.	−52 44·7	E.N.E.	+38	+3			
			Direct.	−52 32·0	E.	+37	+3	−51 47		
			S.	−52 21·5	E.	+37	+3			
			Direct.	−52 31·0	E.S.E.	+ 9	+3	−52 13		
			S.	−52 20·1	E.S.E.	+ 9	+3			
			Direct.	−52 13·2	S.E.	−14	+3	−52 29		
			S.	−52 22·6	S.E.	−14	+3			
			Direct.	−51 51·7	S.S.E.	−32	+3	−52 33		
			S.	−52 16·2	S.S.E.	−32	+3			
			Direct.	−51 21·0	S.	−40	+3	−52 13		
			S.	−51 51·0	S.	−40	+3			
			Direct.	−51 33·0	S.S.W.	−32	+3	−51 58		
			S.	−51 25·0	S.S.W.	−32	+3			
			Direct.	−51 51·0	S.W.	−14	+3	−51 35		
			S.	−51 40·7	S.W.	−14	+3			
			Direct.	−52 22·0	W.S.W.	+ 9	+3	−52 05		
			S.	−52 12·5	W.S.W.	+ 9	+3			
			Direct.	−52 46·8	W.	+37	+3	−52 07		

* Observed on shore; face west.

Direct.	−53° 34′·2
S.	−53 31·8
N.	−53 24·3
N.S.	−53 21·8

Observations of the INCLINATION made in Her Majesty's Ship Terror, with Needle F. C. B., between April 1841 and August 1842.

Observers Captain FRANCIS RAWDON CROZIER, and Mr. THOMAS MOORE, Mate, R.N.

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° '	° '		° '		'	'	° '	° '	
Apr. 19.	Hobarton Magnetic Observatory.		Direct.	−70 29·6	Observed on shore.	....	−35	−70 52	−70 52	A spare needle(marked C.) was used as deflector N. and deflector S.: and the magnets of the apparatus as Mag. N. Mag. S. and Mag. N.S.
			Direct.	−70 25·9		....	−35			
	−42 52	147 24*	Def. N.	−69 33·5		....	−81			
			Def. S.	−70 17·9		....	−35			
			Mag. N.S.	−70 09·6		....	−35			
			Mag. N.	−70 09·9		....	−35			
			Mag. S.	−70 10·7†		....	−35			
July 7.	Running out of Storm Bay.		Direct.	−69 46·5	S.E. ¾ E.	−32	−35	−71 00	−71 00	Ship steady.
			Def. N.	−69 29·9	S.E. ¾ E.	−32	−81			
			Def. S.	−69 38·8	S.E. ¾ E.	−32	−35			
			Direct.	−69 51·2	S.E. ¾ E.	−32	−35			
8.	−43 03	148 20	Direct.	−70 58·0	W. ½ N.	+27	−35	−71 18	−70 44	Ship very steady.
			Def. N.	−70 50·4	W. ½ N.	+27	−81			
			Def. S.	−71 02·0	W. ½ N.	+27	−35			
			Direct.	−71 04·0	W. ½ N.	+27	−35			
9.	−42 24	149 30	Direct.	−70 43·3	N.N.W.	+76	−35	−70 10		
			Def. N.	−70 34·1	N.N.W.	+76	−81			
			Def. S.	−70 36·0	N.N.W.	+76	−35			
			Direct.	−70 45·5	N.N.W.	+76	−35			
10.	−40 51	149 28	Direct.	−69 42·7	N. by W.	+78	−35	−69 05	−69 05	Ship very steady.
			Def. N.	−69 19·7	N. by W.	+78	−81			
			Def. S.	−69 37·7	N. by W.	+78	−35			
			Direct.	−69 47·0	N. by W.	+78	−35			
11.	−38 17	150 22	Direct.	−67 41·3	N. by E.	+73	−35	−66 57	−66 57	Ship very steady.
			Def. N.	−67 23·3	N. by E.	+73	−81			
			Def. S.	−67 07·0	N. by E.	+73	−35			
			Direct.	−67 42·7	N. by E.	+73	−35			

* Observations at Hobarton to obtain corrections for the ship's attraction.

June 22. At anchor	Direct...	−70 14·3	W.	Direct...	−69 54·9	E.
	Def. N...	−69 52·5	W.	Def. N...	−69 21·9	E.
	Direct...	−69 59·0	W.S.W.	Direct...	−70 14·1	E.N.E.
	Def. N...	−69 38·4	W.S.W.	Def. N...	−69 51·5	E.N.E.
	Direct...	−69 24·5	S.W.	Direct...	−70 21·4	N.E.
	Def. N...	−68 49·9	S.W.	Def. N...	−70 12·0	N.E.
	Direct...	−68 57·0	S.S.W.	Direct...	−70 31·6	N.N.E.
	Def. N...	−68 38·2	S.S.W.	Def. N...	−70 16·9	N.N.E.
	Direct...	−68 37·5	S.	Direct...	−70 48·2	N.
	Def. N...	−68 30·9	S.	Def. N...	−70 28·2	N.
	Direct...	−68 40·0	S.S.E.	Direct...	−71 01·8	N.N.W.
	Def. N...	−68 14·3	S.S.E.	Def. N...	−70 42·3	N.N.W.
	Direct...	−68 52·2	S.E.	Direct...	−70 59·6	N.W.
	Def. N...	−68 26·4	S.E.	Def. N...	−70 13·9	N.W.
	Direct...	−69 22·6	E.S.E.	Direct...	−70 47·6	W.N.W.
	Def. N...	−68 59·1	E.S.E.	Def. N...	−70 32·5	W.N.W.

† Observed on shore; face west.	Direct.......	−70 39·9	Mag. N.S. ..	−70 54·4	Mag. S.	−70 39·9
	Direct.......	−70 40·2	Mag. N.	−70 54·4	Def. N.	−71 25·9
	Def. S.......	−70 40·0				

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° '	° '		° '		'	'	° '	° '	
July 12.	−37 28	151 30	Direct.	−66 45·1	N.E. ½ N.	+63	−35	−66 22	−66 22	Ship steering steadily.
			Def. N.	−66 40·0	N.E. ½ N.	+63	−81			
			Def. S.	−66 19·1	N.E. ½ N.	+63	−35			
			Direct.	−66 49·7	N.E. ½ N.	+63	−35			
13.	−36 21	151 39	Direct.	−66 24·5	N.N.W. ¼ W.	+69	−35	−66 11	−66 11	Ship unsteady.
			Def. N.	−66 35·9	N.N.W. ¼ W.	+69	−81			
			Direct.	−66 29·1	N.N.W. ¼ W.	+69	−35			
14.	−34 06	151 19	Direct.	−63 25·9	N.	+67	−35	−62 58	−62 58	Steering steadily.
			Def. N.	−63 08·4	N.	+67	−81			
			Def. S.	−63 11·9	N.	+67	−35			
			Direct.	−63 29·6	N.	+67	−35			
19.	Garden Island,		Direct.	−62 29·3*	Observed on shore.	....	−35	−62 59	−62 59	
	Sydney.		Def. N.	−61 36·7		....	−81			
	−33 51	151 17	Def. S.	−62 29·8		....	−35			
			Mag. N.	−62 15·2		....	−35			
			Mag. S.	−62 17·4		....	−35			
			Mag. N.S.	−62 14·0		....	−35			
			Direct.	−62 28·8		....	−35			
30.	At anchor.		Direct.	−62 36·6	W. by S.	+12	−35	−63 00	−62 52	Head swell on the 5th, steering badly.
Aug. 4.			Direct.	−63 06·1	W.	+25	−35	−63 16		
			Direct.	−63 03·3	W. ½ S.	+18	−35	−63 20		
5.			Direct.	−62 06·4	S.W. by W.	−16	−35	−62 57		
			Direct.	−62 16·0	S.W. ½ W.	−25	−35	−63 16		
5.	Running out of harbour.		Direct.	−62 52·9	E. by N. ½ N.	+39	−35	−62 49		
			Def. N.	−62 14·1	E. by N. ½ N.	+39	−81	−62 56		
			Def. S.	−62 25·4	E. by N. ½ N.	+39	−35	−62 21		
			Mag. N.	−62 34·4	E. by N. ½ N.	+39	−35	−62 30		
			Mag. S.	−62 44·6	E. by N. ½ N.	+39	−35	−62 41		
			Direct.	−62 43·5	E. by N. ½ N.	+39	−35	−62 40		
6.	−34 01	153 17	Direct.	−62 31·3	E. by N.	+35	−35	−62 30	−62 30	Steering badly.
			Def. N.	−62 06·1	E. by N.	+35	−81			
			Def. S.	−62 28·2	E. by N.	+35	−35			
			Direct.	−62 27·2	E. by N.	+35	−35			
	−33 54	153 54	Direct.	−62 23·7	E. by N.	+35	−35			
			Def. N.	−62 02·6	E. by N.	+35	−81			
			Def. S.	−62 02·8	E. by N.	+35	−35			
			Direct.	−62 24·1	E. by N.	+35	−35			
7.	−33 56	156 38	Direct.	−61 40·6	E. by N.	+35	−35	−61 46	−61 46	Steering wildly.
			Def. N.	−61 09·9	E. by N.	+35	−81			
			Def. S.	−61 40·7	E. by N.	+35	−35			
			Direct.	−61 47·6	E. by N.	+35	−35			
8.	−33 31	160 20	Direct.	−61 17·4	E. by N.	+35	−35	−61 04	−61 04	Steering tolerably.
			Def. N.	−60 38·1	E. by N.	+35	−81			
			Def. S.	−60 22·1	E. by N.	+35	−35			
			Direct.	−61 14·2	E. by N.	+35	−35			
9.	−33 42	164 05	Direct.	−60 40·6	E.	+26	−35	−60 52	−60 52	Steering badly.
			Def. N.	−60 17·2	E.	+26	−81			
			Def. S.	−60 30·8	E.	+26	−35			
			Direct.	−60 37·7	E.	+26	−35			

* Observed on shore; face west.

Direct.	−62° 52'·9	Mag. N.	−63° 00'·8
Def. N.	−63 00·7	Mag. S.	−62 57·0
Def. S.	−62 52·4		

Mag. N. and S. −63° 03'·7
Direct. ...... −62 52·3

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Aug. 10.	−33° 47′	166° 39′	Direct.	−59° 59′·9	E. by N. ½ N.	+39′	−35′	° ′	° ′	
			Def. N.	−59 56·7	E. by N. ½ N.	+39	−81			
			Def. S.	−59 38·1	E. by N. ½ N.	+39	−35	−60 02		
			Direct.	−60 02·2	E. by N. ½ N.	+39	−35			
	−33 42	166 36	Direct.	−59 42·3	E.	+26	−35			
			Def. N.	−59 00·3	E.	+26	−81			
			Def. S.	−59 42·7	E.	+26	−35		−59 55	Long swell, motion quick, steering steadily.
			Mag. N.	−59 21·1	E.	+26	−35	−59 49		
			Mag. S.	−59 39·9	E.	+26	−35			
			Direct.	−60 02·2	E. by N.	+36	−35			
11.	−33 34	167 37	Direct.	−60 13·9	N.E. by E.	+50	−35			
			Def. N.	−59 18·4	N.E. by E.	+50	−81			
			Def. S.	−60 03·5	N.E. by E.	+50	−35			
			Mag. N.	−60 04·1	N.E. by E.	+50	−35	−59 49		
			Mag. S.	−60 01·4	N.E. by E.	+50	−35		−59 58	Wind light, with a heavy swell, motion quick.
			Mag. N.S.	−59 54·0	N.E. by E.	+50	−35			
			Direct.	−60 09·5	N.E. by E.	+50	−35			
	−33 31	167 41	Direct.	−59 53·1	E.	+26	−35	−60 07		
			Def. N.	−59 17·2	E.	+26	−81			
12.	−33 00	169 20	Direct.	−58 59·8	E.N.E.	+43	−35			
			Def. N.	−58 22·6	E.N.E.	+43	−81			
			Def. S.	−58 56·9	E.N.E.	+43	−35			
			Mag. N.	−58 36·5	E.N.E.	+43	−35	−58 43		
			Mag. S.	−58 23·1	E.N.E.	+43	−35		−58 43	Motion quick, steering well.
			Direct.	−58 56·7	E.N.E.	+43	−35			
			Direct.	−59 10·4	N.E.	+52	−35			
			Mag. N.S.	−58 40·5	N.E.	+52	−35	−58 43		Ship unsteady.
			Direct.	−59 09·1	N.E.	+52	−35			
13.	−32 12	170 27	Direct.	−56 21·9	S.E. by E.	−10	−35			
			Def. N.	−56 00·5	S.E. by E.	−10	−81	−57 13		
			Def. S.	−56 18·1	S.E. by E.	−10	−35			
			Direct.	−56 24·6	S.E. by E.	−10	−35			
14.	−32 11	171 20	Direct.	−56 58·5	S.E. by E.	−10	−35		−57 28	Much motion, steering well.
			Def. N.	−56 11·3	S.E. by E.	−10	−81			
			Def. S.	−56 40·0	S.E. by E.	−10	−35			
			Mag. N.	−56 46·1	S.E. by E.	−10	−35	−57 36		
			Mag. N.S.	−56 55·9	S.E. by E.	−10	−35			
			Mag. S.	−56 49·8	S.E. by E.	−10	−35			
			Direct.	−56 51·0	S.E. by E.	−10	−35			
15.	−33 55	171 59	Direct.	−57 39·5	E. by S.	+14	−35	−58 17		
			Def. N.	−57 06·2	E. by S.	+14	−81			
			Direct.	−58 22·1	E. ½ N.	+32	−35		−58 24	A head sea, table very unsteady.
			Def. N.	−57 57·4	E. ½ N.	+32	−81	−58 32		
			Direct.	−58 20·8	E. ½ N.	+32	−35			
	−33 58	172 06	Direct.	−57 57·7	E.S.E.	+ 4	−35			
			Def. N.	−57 32·5	E.S.E.	+ 4	−81			
			Def. S.	−57 22·1	E.S.E.	+ 4	−35			
			Mag. N.	−57 24·9	E.S.E.	+ 4	−35	−58 14	−58 14	Head sea, steering badly, ship unsteady.
			Mag. N.S.	−57 30·0	E.S.E.	+ 4	−35			
			Mag. S.	−57 22·9	E.S.E.	+ 4	−35			
			Direct.	−58 00·5	E.S.E.	+ 4	−35			
16.	−34 15	172 50	Direct.	−59 25·6	N.W. ½ N.	+51	−35			
			Def. N.	−59 00·3	N.W. ½ N.	+51	−81			
			Def. S.	−58 46·2	N.W. ½ N.	+51	−35			
			Mag. N.	−59 01·4	N.W. ½ N.	+51	−35	−58 48		Head sea, steering badly, ship unsteady.
			Mag. N.S.	−58 55·8	N.W. ½ N.	+51	−35		−58 48	

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Aug. 16.	−34° 15′	172° 50′	Mag. S.	−58° 08′·6	N.W. ½ N.	+51′	−35′	−58° 48′	−58° 48′	Head sea, steering badly, ship unsteady.
			Direct.	−59 24·6	N.W. ½ N.	+51	−35			
			Direct.	−58 26·9	E. by S. ½ S.	+ 7	−35	−58 46		
			Mag. N.S.	−58 04·7	E. by S. ½ S.	+ 7	−35			
			Direct.	−58 23·1	E. by S. ½ S.	+ 7	−35			
17.	−34 24	173 43	Direct.	−58 33·2	E. by S. ½ S.	+ 7	−35	−59 00	−59 00	Strong wind, a good deal of motion.
			Def. N.	−58 21·7	E. by S. ½ S.	+ 7	−81			
			Def. S.	−58 23·3	E. by S. ½ S.	+ 7	−35			
			Mag. N.	−58 25·9	E. by S. ½ S.	+ 7	−35			
			Mag. N.S.	−58 25·5	E. by S. ½ S.	+ 7	−35			
			Mag. S.	−58 21·4	E. by S. ½ S.	+ 7	−35			
			Direct.	−58 26·8	E. by S. ½ S.	+ 7	−35			
18.	Running into the Bay of Islands.		Direct.	−58 20·6	S.W.	−30	−35	−59 36	−59 36	Heavy sea, steering wildly.
			Def. N.	−58 08·4	S.W.	−30	−81			
			Direct.	−58 19·2	S.W.	−30	−35			
Oct. 21.	Bay of Islands, New Zealand.		Direct.	−59 00·4	Observed on shore.		−35	−59 34	−59 25	Magnetic observatory.
			Def. N.	−57 57·5			−81	−59 18		
	−35 16	174 00	Def. S.	−59 05·1			−35	−59 40		
			Mag. N.	−58 41·0			−35	−59 16		
			Mag. N.S.	−58 43·6			−35	−59 19		
			Mag. S.	−58 38·4			−35	−59 13		
			Direct.	−59 01·0			−35	−59 36		
29.			Direct.	−59 00·8			−35	−59 36		
			Def. N.	−57 58·4			−81	−59 19		
			Def. S.	−58 59·2			−35	−59 34		
			Mag. N.	−58 38·7			−35	−59 14		
			Mag. N.S.	−58 40·3			−35	−59 15		
			Mag. S.	−58 37·1			−35	−59 12		
			Direct.	−59 02·2*			−35	−59 37		
Nov. 23.	Running out of Bay of Islands, about one mile from Piercy Island.		Direct.	−57 50·2	S.E. by E.	−17	−35	−58 42	−59 20	Very steady.
			Direct.	−58 34·3	E. by S.	+11	−35	−58 58		
			Def. N.	−57 57·1	E. by S.	+11	−81	−59 07		
			Def. S.	−58 40·9	E. by S.	+11	−35	−59 05		
			Direct.	−58 34·2	E. by S.	+11	−35	−58 58		
24.	−36 20	177 27	Direct.	−59 13·5	E.S.E.	− 5	−35	−59 53		Ship unsteady.
			Def. N.	−58 23·2	E.S.E.	− 5	−81	−59 49		
			Def. S.	−58 53·7	E.S.E.	− 5	−35	−59 34		
			Mag. N.	−58 39·2	E.S.E.	− 5	−35	−59 19		
			Mag. N.S.	−58 37·0	E.S.E.	− 5	−35	−59 17		
			Mag. S.	−58 37·3	E.S.E.	− 5	−35	−59 17		
			Direct.	−59 14·7	E.S.E.	− 5	−35	−59 55		
25.	−38 00	179 34	Direct.	−59 41·1	S.E. by S.	−40	−35	−60 56	−60 37	Head sea, table unsteady.
			Def. N.	−58 31·6	S.E. by S.	−40	−81	−60 33		
			Def. S.	−58 54·4	S.E. by S.	−40	−35	−60 09		
			Mag. N.	−58 54·0	S.E. by S.	−40	−35	−60 09		
			Mag. N.S.	−59 02·5	S.E. by S.	−40	−35	−60 17		
			Mag. S.	−58 55·4	S.E. by S.	−40	−35	−60 10		
			Direct.	−59 37·6	S.E. by S.	−40	−35	−60 53		
	−38 27	179 59	Direct.	−60 11·8	S.E. by E. ½ E.	−12	−35	−60 59		

* Observed on shore; face west.

Direct....	Oct. 21.	−59° 47′·6	Oct. 29.	−59° 54′·6
Def. N. ..	Oct. 21.	−60 13·9	Oct. 29.	−60 10·7
Def. S. ..	Oct. 21.	−60 00·5	Oct. 29.	−60 06·3
Mag. N...	Oct. 21.	−60 10·3	Oct. 29.	−60 13·1
Mag. N.S.	Oct. 21.	−60 13·7	Oct. 29.	−60 01·2
Mag. S...	Oct. 21.	−60 07·4	Oct. 29.	−60 12·8
Direct....	Oct. 21.	−59 48·6	Oct. 29.	−59 58·5

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Nov. 25.	−38° 27′	179° 59′	Def. N.	−59° 06′·2	S.E. by E. ½ E.	−12′	−81′	−60° 39′	−60° 37′	Head sea, table unsteady.
			Def. S.	−60 03·3	S.E. by E. ½ E.	−12	−35	−60 50		
			Mag. N.	−59 51·3	S.E. by E. ½ E.	−12	−35	−60 38		
			Mag. N.S.	−59 46·0	S.E. by E. ½ E.	−12	−35	−60 33		
			Mag. S.	−60 00·6	S.E. by E. ½ E.	−12	−35	−60 48		
			Direct.	−60 12·9	S.E. by E. ½ E.	−12	−35	−61 00		
	−38 57	181 18	Direct.	−60 00·6	E.S.E.	− 5	−35	−60 41		Heavy sea, much motion, observations not satisfactory.
26.	−38 48	182 05	Direct.	−61 08·6	E.S.E.	− 5	−35	−61 49	−61 21	Tolerably steady.
			Def. N.	−60 00·6	E.S.E.	− 5	−81	−61 27		
			Def. S.	−60 37·7	E.S.E.	− 5	−35	−61 18		
			Direct.	−60 11·9	S.E.	−31	−35	−61 18		
			Def. N.	−59 07·5	S.E.	−31	−81	−61 00		
			Def. S.	−59 48·8	S.E.	−31	−35	−60 55		
			Mag. N.	−59 36·8	S.E.	−31	−35	−60 43		
			Mag. N.S.	−59 48·5	S.E.	−31	−35	−60 54		
			Mag. S.	−59 38·9	S.E.	−31	−35	−60 45		
			Direct.	−60 08·7	S.E.	−31	−35	−61 15		
	−39 02	182 35	Direct.	−61 14·4	E.S.E.	− 5	−35	−61 54		Head swell with considerable motion.
			Def. N.	−60 13·3	E.S.E.	− 5	−81	−61 39		
			Def. S.	−60 46·2	E.S.E.	− 5	−35	−61 26		
			Mag. N.	−60 42·2	E.S.E.	− 5	−35	−61 22		
			Mag. N.S.	−60 51·5	E.S.E.	− 5	−35	−61 31		
			Mag. N.	−60 06·7	E.S.E.	− 5	−35	−61 47		
			Direct.	−61 13·9	E.S.E.	− 5	−35	−61 54		
27.	−39 14	182 54	Direct.	−60 24·6	S.E. by E.	−20	−35	−61 20	−61 15	Tolerably steady, steering well.
			Def. N.	−59 12·0	S.E. by E.	−20	−81	−60 53		
			Def. S.	−60 30·1	S.E. by E.	−20	−35	−61 25		
			Mag. N.	−59 54·5	S.E. by E.	−20	−35	−60 50		
			Mag. N.S.	−59 55·1	S.E. by E.	−20	−35	−60 50		
			Mag. S.	−60 15·2	S.E. by E.	−20	−35	−61 10		
			Direct.	−60 31·5	S.E. by E.	−20	−35	−61 27		
	−39 15	183 02	Direct.	−59 41·2	S. by E. ½ E.	−56	−35	−61 12		Slight motion.
			Direct.	−59 41·8	S. ½ E.	−61	−35	−61 18		
	−39 31	183 00	Direct.	−59 51·6	S. by E.	−60	−35	−61 27		Table steady.
			Def. N.	−59 13·4	S. by E.	−60	−81	−61 34		Slight motion, steering well.
			Def. S.	−59 59·5	S. by E.	−60	−35	−61 34		
			Mag. N.	−59 23·9	S. by E.	−60	−35	−60 59		
			Mag. N.S.	−59 30·9	S. by E.	−60	−35	−61 06		
			Mag. S.	−59 44·6	S. by E.	−60	−35	−61 20		
			Direct.	−59 55·0	S. by E.	−60	−35	−61 30		
28.	−40 35	183 00	Direct.	−61 14·0	E.S.E.	− 5	−35	−61 54		
			Direct.	−60 47·6	S.E.	−33	−35	−61 56	−61 56	
			Def. N.	−59 58·5	S.E.	−33	−81	−61 53		
			Def. S.	−60 57·6	S.E.	−33	−35	−62 06		
			Mag. N.	−60 28·1	S.E.	−33	−35	−61 36		
			Mag. N.S.	−60 29·6	S.E.	−33	−35	−61 38		
			Mag. S.	−60 46·0	S.E.	−33	−35	−61 54		
			Direct.	−60 47·3	S.E.	−33	−35	−61 55		
	−40 50	183 11	Direct.	−60 51·2	S.S.E. ½ E.	−48	−35	−62 14		
			Def. N.	−59 43·5	S.S.E. ½ E.	−48	−81	−61 53		
			Def. S.	−60 55·4	S.S.E. ½ E.	−48	−35	−62 18		
			Mag. N.	−60 13·9	S.S.E. ½ E.	−48	−35	−61 37		
			Mag. N.S.	−60 30·0	S.S.E. ½ E.	−48	−35	−61 53		
			Mag. S.	−60 30·1	S.S.E. ½ E.	−48	−35	−61 53		
			Direct.	−60 54·0	S.S.E. ½ E.	−48	−35	−62 17		

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Nov. 29.	−41° 34′	183° 40′	Direct.	−61° 27′·5	s. by E.	−60′	−35′	−63° 03′	−62° 57′	Slight motion, steering well.
			Def. N.	−60 27·5	s. by E.	−60	−81	−62 49		
			Def. S.	−61 31·3	s. by E.	−60	−35	−63 06		
			Mag. N.	−61 37·1	s. by E.	−60	−35	−63 12		
			Mag. N.S.	−61 03·5	s. by E.	−60	−35	−62 39		
			Mag. S.	−60 58·9	s. by E.	−60	−35	−62 34		
			Direct.	−61 44·5	s. by E.	−60	−35	−63 19		
	−42 40	183 46	Direct.	−62 23·7	s.	−64	−35	−64 03	−63 46	
			Def. N.	−61 02·1	s.	−64	−81	−63 27		
			Def. S.	−62 08·6	s.	−64	−35	−63 48		
			Mag. N.	−61 54·9	s.	−64	−35	−63 34		
			Mag. N.S.	−62 03·6	s.	−64	−35	−63 43		
			Mag. S.	−62 01·2	s.	−64	−35	−63 40		
			Direct.	−62 29·6	s.	−64	−35	−64 09		
30.	−43 33	183 10	Direct.	−63 26·2	s. ½ w.	−63	−35	−65 04	−65 22	Table steady, steering well.
			Def. N.	−62 29·3	s. ½ w.	−63	−81	−64 53		
			Def. S.	−63 58·6	s. ½ w.	−63	−35	−65 37		
			Mag. N.	−63 16·8	s. ½ w.	−63	−35	−64 55		
			Mag. N.S.	−62 58·2	s. ½ w.	−63	−35	−64 36		
			Mag. S.	−63 46·3	s. ½ w.	−63	−35	−65 24		
			Direct.	−63 26·2	s. ½ w.	−63	−35	−65 04		
	−43 50	183 00	Direct.	−63 43·0	s. by w.	−62	−35	−65 20		Cross sea, motion slight.
	−44 15		Direct.	−64 07·3	s. by w.	−62	−35	−65 44		
			Def. N.	−63 29·4	s. by w.	−62	−81	−65 52		
			Def. S.	−63 59·7	s. by w.	−62	−35	−65 37		
			Mag. N.	−63 51·9	s. by w.	−62	−35	−65 29		
			Mag. N.S.	−63 52·9	s. by w.	−62	−35	−65 30		
			Mag. S.	−63 58·1	s. by w.	−62	−35	−65 35		
			Direct.	−64 11·4	s. by w.	−62	−35	−65 48		
Dec. 1.	−45 30	183 12	Direct.	−65 46·1	s.E. by E.	−24	−35	−66 45	−66 43	Much pitching, steering well.
			Def. N.	−65 01·6	s.E. by E.	−24	−81	−66 47		
			Def. S.	−65 19·5	s.E. by E.	−24	−35	−66 19		
			Mag. N.	−65 14·3	s.E. by E.	−24	−35	−66 13		
			Mag. N.S.	−65 31·7	s.E. by E.	−24	−35	−66 31		
			Mag. S.	−66 00·8	s.E. by E.	−24	−35	−67 00		
			Direct.	−65 40·0	s.E. by E.	−24	−35	−66 39		
	−45 48	183 25	Direct.	−65 43·9	s.E. ½ E.	−31	−35	−66 50		
			Def. N.	−64 55·1	s.E. ½ E.	−31	−81	−66 47		
			Def. S.	−65 36·8	s.E. ½ E.	−31	−35	−66 43		
			Mag. N.	−65 54·2	s.E. ½ E.	−31	−35	−67 00		
			Mag. N.S.	−65 40·5	s.E. ½ E.	−31	−35	−66 47		
			Mag. S.	−65 49·2	s.E. ½ E.	−31	−35	−66 55		
			Direct.	−65 47·4	s.E. ½ E.	−31	−35	−66 53		
2.	−47 13	184 30	Direct.	−66 30·4	s.E. by E. ½ E.	−18	−35	−67 23	−67 32	Ship pitching, but steering well.
			Def. N.	−65 41·8	s.E. by E. ½ E.	−18	−81	−67 21		
			Def. S.	−66 43·2	s.E. by E. ½ E.	−18	−35	−67 36		
			Mag. N.	−66 31·4	s.E. by E. ½ E.	−18	−35	−67 24		
			Mag. N.S.	−66 30·3	s.E. by E. ½ E.	−18	−35	−67 23		
			Mag. S.	−66 37·0	s.E. by E. ½ E.	−18	−35	−67 30		
			Direct.	−66 34·6	s.E. by E. ½ E.	−18	−35	−67 28		
	−47 39	184 55	Direct.	−66 54·4	s.E. by E.	−26	−35	−67 55		Very steady.
			Def. N.	−65 36·6	s.E. by E.	−26	−81	−67 24		
			Def. S.	−66 40·1	s.E. by E.	−26	−35	−67 41		
			Mag. N.	−66 21·5	s.E. by E.	−26	−35	−67 23		
			Mag. N.S.	−66 35·4	s.E. by E.	−26	−35	−67 36		
			Mag. S.	−66 34·7	s.E. by E.	−26	−35	−67 36		
			Direct.	−66 47·4	s.E. by E.	−26	−35	−67 48		

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Dec. 3.	−48 18	185 54	Direct.	−67 34·4	S.E. by E.	−27	−35	−68 36	° ′	
			Def. N.	−66 19·7	S.E. by E.	−27	−81	−68 08		
			Def. S.	−67 23·9	S.E. by E.	−27	−35	−68 26		
			Mag. N.	−67 17·7	S.E. by E.	−27	−35	−68 20		
			Mag. N.S.	−67 21·9	S.E. by E.	−27	−35	−68 24		
			Mag. S.	−67 17·1	S.E. by E.	−27	−35	−68 19		
			Direct.	−67 38·6	S.E. by E.	−27	−35	−68 41		
	−48 48	186 38	Direct.	−67 46·6	E.S.E.	−11	−35	−68 33	−68 40	Very steady.
	−49 05	186 54	Direct.	−68 01·5	S.E. by E. ½ E.	−19	−35	−68 56		
			Def. N.	−67 07·3	S.E. by E. ½ E.	−19	−81	−68 47		
			Def. S.	−67 55·0	S.E. by E. ½ E.	−19	−35	−68 49		
			Mag. N.	−67 49·5	S.E. by E. ½ E	−19	−35	−68 44		
			Mag. N.S.	−67 44·7	S.E. by E. ½ E.	−19	−35	−68 39		
			Mag. S.	−67 53·8	S.E. by E. ½ E.	−19	−35	−68 48		
			Direct.	−68 54·3	S.E. by E. ½ E.	−19	−35	−69 48		
4.	−49 24	187 23	Direct.	−68 53·5	N.E. by E.	+54	−35	−68 35		
			Direct.	−68 33·0	E. ½ N.	+26	−35	−68 42		
			Direct.	−68 29·8	E.	+20	−35	−68 45		
			Direct.	−68 42·3	E.N.E.	+45	−35	−68 32		Steady.
			Direct.	−68 28·7	W.S.W.	−12	−35	−69 16		
			Direct.	−68 45·7	W.	+20	−35	−69 01		
			Direct.	−68 52·2	E.	+20	−35	−69 07		
			Def. N.	−67 28·0	E.	+20	−81	−68 29	−68 59	
			Direct.	−68 48·0	E. by S.	+ 4	−35	−69 19		
			Def. N.	−67 29·5	E. by S.	+ 4	−81	−68 47		
			Def. S.	−68 52·0	E. by S.	+ 4	−35	−69 23		
			Mag. N.	−68 29·0	E. by S.	+ 4	−35	−69 00		Swell from northward. Table steady.
			Mag. N.S.	−68 28·1	E. by S.	+ 4	−35	−68 59		
			Mag. S.	−68 42·7	E. by S.	+ 4	−35	−69 14		
			Direct.	−69 01·0	E. by S.	+ 4	−35	−69 32		
5.	−49 23	188 54	Direct.	−68 43·9	E. by S.	+ 4	−35	−69 15		
			Def. N.	−67 31·6	E. by S.	+ 4	−81	−68 49		
			Def. S.	−68 42·2	E. by S.	+ 4	−35	−69 13		
			Mag. N.	−68 42 6	E. by S.	+ 4	−35	−69 14		
			Mag. N.S.	−68 40·1	E. by S.	+ 4	−35	−69 11		
			Mag. S.	−68 30·6	E. by S.	+ 4	−35	−69 02		
			Direct.	−68 44·2	E. by S.	+ 4	−35	−69 15	−68 55	Table steady.
	−49 38	189 44	Direct.	−68 15·9	E. by S.	+ 4	−35	−68 47		
			Def. N.	−67 25·5	E. by S.	+ 4	−81	−68 43		
			Def. S.	−68 06·1	E. by S.	+ 4	−35	−68 37		
			Mag. N.	−67 57·8	E. by S.	+ 4	−35	−68 29		
			Mag. N.S.	−68 01·6	E. by S.	+ 4	−35	−68 33		
			Mag. S.	−68 22·7	E. by S.	+ 4	−35	−68 54		
			Direct.	−68 14·3	E. by S.	+ 4	−35	−68 45		
6.	−49 50	190 46	Direct.	−68 12·9	E. by S.	+ 4	−35	−68 44		
			Def. N.	−67 22·6	E. by S.	+ 4	−81	−68 40		
			Def. S.	−68 09·6	E. by S.	+ 4	−35	−68 41		
			Mag. N.	−68 07·4	E. by S.	+ 4	−35	−68 38		
			Mag. N.S.	−68 05·2	E. by S.	+ 4	−35	−68 36		
			Mag. S.	−68 21·5	E. by S.	+ 4	−35	−68 53		Swell from northward.
			Direct.	−68 16·3	E. by S.	+ 4	−35	−68 47	−68 43	Table steady.
	−50 02	191 21	Direct.	−68 09·8	E. by S.	+ 4	−35	−68 41		
	−50 08	191 39	Direct.	−68 17·0	E. by S.	+ 4	−35	−68 48		
			Def. N.	−67 22·2	E. by S.	+ 4	−81	−68 39		
			Def. S.	−68 16·8	E. by S.	+ 4	−35	−68 48		
			Mag. N.	−68 09·2	E. by S.	+ 4	−35	−68 40		
			Mag. N.S.	−68 08·4	E. by S.	+ 4	−35	−68 39		
			Mag. S.	−68 18·2	E. by S.	+ 4	−35	−68 49		

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Dec. 7.	−50 32	191 52	Direct.	−68 24·2	S.E. by E.	−27	−35	−69 26		
			Def. N.	−67 47·4	S.E. by E.	−27	−81	−69 35		
			Def. S.	−68 18·1	S.E. by E.	−27	−35	−69 20		
			Mag. N.	−68 02·0	S.E. by E.	−27	−35	−69 04		
			Mag. N.S.	−67 50·3	S.E. by E.	−27	−35	−68 52		
			Mag. S.	−68 07·9	S.E. by E.	−27	−35	−69 10		
			Direct.	−68 28·1	S.E. by E.	−27	−35	−69 30		
	−50 45	192 19	Direct.	−68 31·2	S.E. ½ E.	−35	−35	−69 41	−69 25	Table steady.
			Def. N.	−67 31·3	S.E. ½ E.	−35	−81	−69 27		
			Def. S.	−68 08·4	S.E. ½ E.	−35	−35	−69 18		
			Mag. N.	−68 39·3	S.E. ½ E.	−35	−35	−69 49		
			Mag. N.S.	−68 30·9	S.E. ½ E.	−35	−35	−69 41		
			Mag. S.	−68 13·2	S.E. ½ E.	−35	−35	−69 23		
			Direct.	−68 30·3	S.E. ½ E.	−35	−35	−69 40		
8.	−51 37	194 00	Direct.	−69 18·9	E. by S.	+ 4	−35	−69 50		
			Def. N.	−68 23·8	E. by S.	+ 4	−81	−69 41		
			Def. S.	−69 20·4	E. by S.	+ 4	−35	−69 51		
			Mag. N.	−69 19·6	E. by S.	+ 4	−35	−69 51		
			Mag. N.S.	−69 13·8	E. by S.	+ 4	−35	−69 45		
			Mag. S.	−69 31·4	E. by S.	+ 4	−35	−70 02		
			Direct.	−69 22·4	E. by S.	+ 4	−35	−69 53		
			Direct.	−69 24·6	E. by S.	+ 4	−35	−69 56	−69 51	Table steady, steering indifferently.
	−52 00	194 53	Direct.	−69 29·8	E. by S.	+ 4	−35	−70 01		
			Def. N.	−68 30·1	E. by S.	+ 4	−81	−69 47		
			Def. S.	−69 17·1	E. by S.	+ 4	−35	−69 48		
			Mag. N.	−69 08·9	E. by S.	+ 4	−35	−69 40		
			Mag. N.S.	−69 11·7	E. by S.	+ 4	−35	−69 43		
			Mag. S.	−69 29·7	E. by S.	+ 4	−35	−70 01		
			Direct.	−69 27·0	E. by S.	+ 4	−35	−69 58		
9.	−52 14	197 49	Direct.	−69 41·0	E. by S.	+ 4	−35	−70 12		
			Def. N.	−68 37·6	E. by S.	+ 4	−81	−69 55		
			Def. S.	−69 29·3	E. by S.	+ 4	−35	−70 00		
			Mag. N.	−69 38·3	E. by S.	+ 4	−35	−70 09		
			Mag. N.S.	−69 56·9	E. by S.	+ 4	−35	−70 28		
			Mag. S.	−69 35·8	E. by S.	+ 4	−35	−70 07	−70 10	
			Direct.	−69 42·6	E. by S.	+ 4	−35	−70 14		
	−52 32	198 31	Direct.	−69 41·2	E. by S.	+ 4	−35	−70 12		Motion quick, steering wild.
10.	−53 01	202 16	Direct.	−69 47·1	E. by S.	+ 4	−35	−70 18		Strong wind, heavy sea.
			Mag. N.S.	−69 19·7	E. by S.	+ 4	−35	−69 51		Motion violent, steering well.
			Direct.	−69 56·5	E. by S.	+ 4	−35	−70 28		
11.	−52 51	203 56	Direct.	−69 53·3	E. ½ N.	+26	−35	−70 02		
			Def. N.	−68 59·6	E. ½ N.	+26	−81	−69 55		
			Def. S.	−69 59·1	E. ½ N.	+26	−35	−70 08		
			Mag. N.	−69 36·5	E. ½ N.	+26	−35	−69 45		
			Mag. N.S.	−69 30·2	E. ½ N.	+26	−35	−69 39	−70 01	Head sea, table not very steady.
			Mag. S.	−69 55·8	E. ½ N.	+26	−35	−70 05		
			Direct.	−70 04·7	E. ½ N.	+26	−35	−70 14		
			Direct.	−70 00·9	E. ½ S.	+12	−35	−70 24		
12.	−52 53	205 07	Direct.	−69 14·2	E.S.E	−12	−35	−70 01		A head swell, steering well.
			Def. N.	−67 53·9	E.S.E.	−12	−81	−69 27		
			Def. S.	−68 55·7	E.S.E.	−12	−35	−69 43		
			Mag. N.	−68 45·1	E.S.E.	−12	−35	−69 32		
			Mag. N.S.	−68 19·8	E.S.E.	−12	−35	−69 07		
			Mag. S.	−68 53·5	E.S.E.	−12	−35	−69 41		
			Direct.	−69 16·4	E.S.E.	−12	−35	−70 03		
	−53 12	205 40	Direct.	−69 19·3	E.S.E.	−12	−35	−70 06	−69 52	

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Dec. 12.	−53° 31′	206° 14′	Direct.	−69° 18′·8	E.S.E.	−12′	−35′	−70° 06′	−69° 52′	Table steady, steering wild.
			Def. N.	−68 07·1	E.S.E.	−12	−81	−69 40		A slight motion, steering well.
			Def. S.	−69 05·5	E.S.E.	−12	−35	−69 53		
			Mag. N.	−69 07·0	E.S.E.	−12	−35	−69 54		
			Mag. N.S.	−69 01·4	E.S.E.	−12	−35	−69 51		
			Mag. S.	−69 58·3	E.S.E.	−12	−35	−70 45		
			Direct.	−69 19·5	E.S.E.	−12	−35	−70 06		
13.	−54 19	208 24	Direct.	−69 18·1	E.S.E.	−12	−35	−70 05	−70 10	
			Def. N.	−68 59·2	E.S.E.	−12	−81	−70 32		
			Def. S.	−69 02·6	E.S.E.	−12	−35	−69 50		
			Mag. N.	−69 16·0	E.S.E.	−12	−35	−70 03		
			Mag. N.S.	−69 16·0	E.S.E.	−12	−35	−70 03		
			Mag. S.	−69 14·0	E.S.E.	−12	−35	−70 01		Table steady, steering wildly.
			Direct.	−69 16·6	E.S.E.	−12	−35	−70 04		
	−54 53	209 24	Direct.	−69 32·9	E.S.E.	−12	−35	−70 20		
			Def. N.	−68 59·0	E.S.E.	−12	−81	−70 32		
			Def. S.	−69 28·8	E S.E.	−12	−35	−70 16		
			Mag. N.	−69 13·4	E.S.E.	−12	−35	−70 00		
			Mag. N.S.	−69 24·6	E.S.E.	−12	−35	−70 12	−70 21	
			Mag. S.	−70 00·3	E.S.E.	−12	−35	−70 47		
			Direct.	−69 32·6	E.S.E.	−12	−35	−70 20		
			Direct.	−69 39·5	E.S.E.	−12	−35	−70 27		A heavy sea, ship steering badly.
			Def. N.	−68 55·8	F.S.E.	−12	−81	−70 29		
			Direct.	−68 52·9	S.E. by S.	−55	−35	−70 23		A swell from the N.W.
			Def. N.	−68 11·4	S.E. by S.	−55	−81	−70 27		
			Def. S.	−68 27·0	S.E. by S.	−55	−35	−69 57		Ship tolerably steady.
			Mag. N.	−68 59·1	S.E. by S.	−55	−35	−70 29		
			Mag. N.S.	−68 46·1	S.E. by S.	−55	−35	−70 16		
			Mag. S.	−68 34·0	S.E. by S.	−55	−35	−70 04		
			Direct.	−68 52·1	S.E. by S.	−55	−35	−70 22		
14.	−56 14	211 43	Direct.	−70 08·2	S.E. by S.	−57	−35	−71 40	−71 41	
			Def. N.	−69 12·9	S.E. by S.	−57	−81	−71 31		
			Def. S.	−70 10·1	S.E. by S.	−57	−35	−71 42		
			Mag. N.	−70 03·2	S.E. by S.	−57	−35	−71 35		
			Mag. N.S.	−70 06·2	S.E. by S.	−57	−35	−71 38		
			Mag. S.	−70 22·0	S.E. by S.	−57	−35	−71 54		
			Direct.	−70 16·1	S.E. by S.	−57	−35	−71 48		Ship steady.
			Direct.	−70 17·8	S.E. by S.	−57	−35	−71 50		
			Def. N.	−69 11.7	S.E. by S.	−57	−81	−71 30		
			Def. S.	−70 12·1	S.E. by S.	−57	−35	−71 44		
			Mag. N.	−70 04·2	S.E. by S.	−57	−35	−71 36		
			Mag. N.S.	−70 00·2	S.E. by S.	−57	−35	−71 32		
			Mag. S.	−70 22·1	S.E. by S.	−57	−35	−71 54		
			Direct.	−70 17·2	S.E. by S.	−57	−35	−71 49		
	−56 30	211 50	Direct.	−70 19·5	S.E. by S.	−57	−35	−71 52	−72 00	
			Def. N.	−69 29·1	S.E. by S.	−57	−81	−71 47		
			Def. S.	−70 12·7	S.E. by S.	−57	−35	−71 45		
			Mag. N.	−70 05·2	S.E. by S.	−57	−35	−71 37		
			Mag. N.S.	−69 59·7	S.E. by S.	−57	−35	−71 32		
			Mag. S.	−70 35·2	S.E. by S.	−57	−35	−72 07		Ship steady.
			Direct.	−70 22·9	S.E. by S.	−57	−35	−71 55		
15.	−56 53	212 06	Direct.	−70 42·4	S.	−77	−35	−72 34		
			Direct.	−70 50·5	S. by E.	−75	−35	−72 40		
			Direct.	−70 27·5	S.S.E.	−69	−35	−72 12		
			Direct.	−70 30·8	S.E. by S.	−57	−35	−72 03		
			Def. N.	−69 33·8	S.E. by S.	−57	−81	−71 52		

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Dec. 15.	−56° 53′	212° 06′	Def. S.	−70° 26′·1	s.e. by s.	−57′	−35′	−71° 58′	−72° 14′	Ship very steady.
			Mag. N.	−70 12·5	s.e. by s.	−57	−35	−71 45		
			Mag. N.S.	−70 09·6	s.e. by s.	−57	−35	−71 42		
			Mag. S.	−70 34·0	s.e. by s.	−57	−35	−72 06		
			Direct.	−70 30·6	s.e. by s.	−57	−35	−72 03		
	−57 16	212 17	Direct.	−70 37·3	s.s.e.	−69	−35	−72 21		
			Def. N.	−70 00·6	s.s.e.	−69	−81	−72 31		
			Def. S.	−70 54·6	s.s.e.	−69	−35	−72 39		
			Mag. N.	−70 49·7	s.s.e.	−69	−35	−72 34		
			Mag. N.S.	−70 25·1	s.s.e.	−69	−35	−72 09		
			Mag. S.	−70 46·1	s.s.e.	−69	−35	−72 30		
			Direct.	−70 41·5	s.s.e.	−69	−35	−72 26		
16.	−57 44	212 59	Direct.	−71 03·3	s.s.e.	−70	−35	−72 48	−73 09	Ship steady, steering well.
			Def. N.	−70 29·6	s.s.e.	−70	−81	−73 01		
			Def. S.	−71 08·2	s.s.e.	−70	−35	−72 53		
			Mag. N.	−71 09·6	s.s.e.	−70	−35	−72 55		
			Mag. N.S.	−71 02·8	s.s.e.	−70	−35	−72 48		
			Mag. S.	−71 15·7	s.s.e.	−70	−35	−73 01		
			Direct.	−71 11·9	s.s.e.	−70	−35	−72 57		
	−58 28	213 08	Direct.	−71 56·4	s.s.e.	−70	−35	−73 41		
			Def. N.	−71 20·8	s.s.e.	−70	−81	−73 52		
			Def. S.	−71 52·3	s.s.e.	−70	−35	−73 37		
			Mag. N.	−71 39·7	s.s.e.	−70	−35	−73 25	−73 45	Ship steady, steering well.
			Mag. N.S.	−71 23·9	s.s.e.	−70	−35	−73 09		
			Mag. S.	−71 59·3	s.s.e.	−70	−35	−73 44		
			Direct.	−72 04·4	s.s.e.	−70	−35	−73 49		
	−58 44	213 11	Direct.	−72 16·2	s.s.e.	−70	−35	−74 01		
			Def. N.	−71 24·5	s.s.e.	−70	−81	−73 56		
			Def. S.	−72 22·6	s.s.e.	−70	−35	−74 08		
			Mag. N.	−71 57·1	s.s.e.	−70	−35	−73 42		
			Mag. N.S.	−71 47·8	s.s.e.	−70	−35	−73 33		
			Mag. S.	−72 01·3	s.s.e.	−70	−35	−73 46		
			Direct.	−72 16·1	s.s.e.	−70	−35	−74 01		
17.	−60 48	213 51	Direct.	−73 24·1	s.s.e.	−73	−35	−75 12	−75 32	Slight motion, steering well.
			Def. N.	−72 33·2	s.s.e.	−73	−81	−75 07		
			Def. S.	−73 29·4	s.s.e.	−73	−35	−75 17		
			Mag. N.	−73 01·5	s.s.e.	−73	−35	−74 49		
			Mag. N.S.	−73 04·2	s.s.e.	−73	−35	−74 52		
			Mag. S.	−73 31·1	s.s.e.	−73	−35	−75 19		
			Direct.	−73 28·8	s.s.e.	−73	−35	−75 17		
	−61 37	213 54	Direct.	−74 10·9	s. ½ e.	−81	−35	−76 07		Ship steady.
			Def. N.	−73 06·9	s. ½ e.	−81	−81	−75 49		
			Def. S.	−73 59·8	s. ½ e.	−81	−35	−75 56		
			Mag. N.	−73 52·8	s. ½ e.	−81	−35	−75 49		
			Mag. N.S.	−73 39·5	s. ½ e.	−81	−35	−75 36		
			Mag. S.	−74 08·6	s. ½ e.	−81	−35	−76 05		
			Direct.	−74 13·1	s. ½ e.	−81	−35	−76 09		
18.	−62 34	212 34	Direct.	−74 51·6	s. by e.	−79	−35	−76 46	−76 37	Ship steady, sailing amongst loose ice.
			Def. N.	−73 48·3	s. by e.	−79	−81	−76 28		
			Def. S.	−74 43·7	s. by e.	−79	−35	−76 38		
			Mag. N.	−74 23·1	s. by e.	−79	−35	−76 17		
			Mag. N.S.	−74 23·9	s. by e.	−79	−35	−76 18		
			Mag. S.	−74 38·9	s. by e.	−79	−35	−76 33		
			Direct.	−74 46·1	s. by e.	−79	−35	−76 40		
	−62 51	212 50	Direct.	−75 20·5	s. by w.	−79	−35	−77 14		

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Dec. 19.	−63 06	210 55	Direct.	−75 52·3	s.s.w.	−74	−35	−77 41	−77 37	Ship steady, sailing amongst loose ice.
			Direct.	−75 45·3	s. by w.	−80	−35	−77 40		
			Def. N.	−74 56·9	s. by w.	−80	−81	−77 38		
			Def. S.	−75 35·6	s. by w.	−80	−35	−77 31		
			Mag. N.	−75 24·5	s. by w.	−80	−35	−77 20		
			Mag. N.S.	−75 21·2	s. by w.	−80	−35	−77 16		
			Mag. S.	−75 37·8	s. by w.	−80	−35	−77 33		
			Direct.	−75 51·8	s. by w.	−80	−35	−77 47		
	−63 21	209 55	Direct.	−76 08·3	s.w. by s.	−62	−35	−77 45		
			Direct.	−76 00·0	s.s.w. ½ w.	−68	−35	−77 43		
			Direct.	−77 00·8	w. by s. ¾ s.	−12	−35	−77 48		
			Direct.	−76 36·2	s.w. by w. ½ w.	−25	−35	−77 36		
20.	−63 36	208 20	Direct.	−76 13·7	s.s.w.	−74	−35	−78 03	−77 53	Ship steady, steering amongst loose ice.
			Def. N.	−75 10·8	s.s.w.	−74	−81	−77 46		
			Def. S.	−76 04·8	s.s.w.	−74	−35	−77 54		
			Mag. N.	−75 45·5	s.s.w.	−74	−35	−77 35		
			Mag. N.S.	−75 44·8	s.s.w.	−74	−35	−77 34		
			Mag. S.	−76 08·0	s.s.w.	−74	−35	−77 57		
			Direct.	−76 01·3	s. by w.	−80	−35	−77 56		
			Direct.	−76 24·9	s.w. by s.	−62	−35	−78 02		
			Direct.	−76 00·4	s.	−82	−35	−77 57		
			Direct.	−76 45·2	s.w.	−49	−35	−78 09		
			Direct.	−76 24·3	s.w. by s.	−62	−35	−78 01	−77 56	Ship steady, steering amongst loose ice.
			Direct.	−76 45·5	s.w.	−49	−35	−78 10		
	−63 53	208 32	Direct.	−76 06·9	s.	−82	−35	−78 04		
			Def. N.	−75 01·3	s.	−82	−81	−77 44		
			Def. S.	−75 53·4	s.	−82	−35	−77 50		
			Mag. N.	−75 44·5	s.	−82	−35	−77 42		
			Mag. N.S.	−75 36·8	s.	−82	−35	−77 34		
			Mag. S.	−75 57·7	s.	−82	−35	−77 55		
			Direct.	−76 08·9	s.	−82	−35	−78 06		
			Direct.	−76 15·3	s. by w.	−80	−35	−78 10		
21.	−64 11	206 35	Direct.	−76 32·9	s.s.w.	−75	−35	−78 23	−78 30	Ship steady, sailing amongst loose ice.
			Def. N.	−75 31·5	s.s.w.	−75	−81	−78 08		
			Def. S.	−76 29·6	s.s.w.	−75	−35	−78 20		
			Mag. N.	−76 10·0	s.s.w.	−75	−35	−78 00		
			Mag. N.S.	−76 01·2	s.s.w.	−75	−35	−77 51		
			Mag. S.	−76 00·8	s.s.w.	−75	−35	−77 51		
			Direct.	−76 43·1	s. ½ E.	−82	−35	−78 40		
			Direct.	−76 32·7	s. by E.	−81	−35	−78 29		
			Direct.	−76 41·8	s. by E. ½ E.	−78	−35	−78 35		
	−64 51	206 19	Direct.	−77 03·2	s. ¾ E.	−82	−35	−79 00		
			Direct.	−77 06·4	s. by w.	−81	−35	−79 02		
			Def. N.	−76 06·6	s. by w.	−81	−81	−78 49		
			Def. S.	−77 02·2	s. by w.	−81	−35	−78 58		
			Direct.	−77 04·7	s. by w.	−81	−35	−79 01		
22.	−65 19	205 08	Direct.	−77 29·4	s. ½ w.	−83	−35	−79 27	−79 16	Sailing amongst loose ice, very steady.
			Def. N.	−76 37·6	s. ½ w.	−83	−81	−79 22		
			Def. S.	−77 20·3	s. ½ w.	−83	−35	−79 18		
			Mag. N.	−77 08·4	s. ½ w.	−83	−35	−79 06		
			Mag. N.S.	−76 59·9	s. ½ w.	−83	−35	−78 58		
			Mag. S.	−77 30·4	s. ½ w.	−83	−35	−79 28		
			Direct.	−77 28·6	s. ½ w.	−83	−35	−79 27		
			Direct.	−77 26·4	s.	−84	−35	−79 25		
	−65 34	205 00	Direct.	−77 27·8	s.	−84	−35	−79 27		
			Def. N.	−76 20·5	s.	−84	−81	−79 05		

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Dec. 22.	−65° 34′	205° 00′	Def. S.	−77° 14′·7	s.	−84′	−35′	−79° 14′	−79° 16′	Sailing amongst loose ice, very steady.
			Mag. N.	−77 04·0	s.	−84	−35	−79 03		
			Mag. N.S.	−76 53·3	s.	−84	−35	−78 52		
			Mag. S.	−77 23·6	s.	−84	−35	−79 23		
			Direct.	−77 30·4	s. ¾ w.	−82	−35	−79 27		
23.	−65 47	204 19	Direct.	−79 54·8	N.E.	+69	−35	−79 21		
			Direct.	−79 45·9	N.E. ½ E.	+64	−35	−79 17		
			Direct.	−79 30·8	N.E. by E.	+59	−35	−79 07		
			Direct.	−77 34·8	s.	−84	−35	−79 34		
			Def. N.	−76 44·1	s.	−84	−81	−79 29		
			Direct.	−79 12·3	E. by N.	+32	−35	−79 15		
			Def. S.	−79 04·9	E. by N.	+32	−35	−79 08	−79 26	Sailing amongst loose ice, very steady.
			Mag. N.S.	−78 44·5	E. by N.	+32	−35	−78 48		
			Mag. S.	−77 15·9*	E. by N.	+32	−35	−77 19		
			Direct.	−78 10·8	S.W. ¼ S.	−55	−35	−79 41		
			Direct.	−77 46·2	s. by w.	−82	−35	−79 43		
			Def. N.	−77 23·0	s. by w.	−82	−81	−80 06		
			Direct.	−77 45·1	s. ¼ w.	−83	−35	−79 43		
			Direct.	−77 44·6	s. ¾ w.	−82	−35	−79 42		
			Direct.	−77 57·6	S.S.W.	−76	−35	−79 49		
			Direct.	−77 34·4	s.	−84	−35	−79 33		
			Direct.	−79 51·1	N.E. ½ E.	+63	−35	−79 23		
			Direct.	−79 57·6	N.E.	+69	−35	−79 24		
			Direct.	−79 32·1	N.E. by E. ½ E.	+52	−35	−79 15		
			Direct.	−78 18·6	S.E. by E. ½ E.	−27	−35	−79 21	−79 28	Sailing amongst loose ice, very steady.
			Direct.	−78 14·3	S.E. by E.	−36	−35	−79 25		
			Direct.	−78 23·0	E.S.E.	−17	−35	−79 15		
			Direct.	−80 26·0	N.	+86	−35	−79 35		
			Direct.	−80 03·9	N.E. by N.	+75	−35	−79 24		
			Direct.	−80 11·6	N.N.E.	+81	−35	−79 26		
			Direct.	−80 19·4	N. by E.	+85	−35	−79 29		
24.	−65 50	204 08	Direct.	−80 31·9	N. by W.	+85	−35	−79 42		
			Direct.	−80 28·8	N. by W.	+85	−35	−79 39		
			Def. N.	−79 26·9	N. by W.	+85	−81	−79 23		
			Mag. S.	−80 21·4	N. by W.	+85	−35	−79 31		
			Mag. N.	−80 08·5	N. by W.	+85	−35	−79 19		
			Mag. N.S.	−80 00·0	N. by W.	+85	−35	−79 10	−79 30	Ship fast to a piece of ice.
			Direct.	−80 01·8	N.E.	+69	−35	−79 28		
			Mag. S.	−79 50·6	N.E.	+69	−35	−79 17		
			Direct.	−80 29·6	N.N.W.	+81	−35	−79 44		
			Direct.	−80 29·2	N.W.	+69	−35	−79 55		
			Direct.	−79 01·3	E.	+16	−35	−79 19		
25.	−66 01	204 00	Direct.	−79 09·2	E. by N.	+32	−35	−79 12		
			Direct.	−78 56·5	E. ¾ S.	+ 4	−35	−79 28		
			Direct.	−80 31·4	N.W. ¼ N.	+70	−35	−79 56		
			Direct.	−78 39·0	E. by S. ¾ S.	−12	−35	−79 26		
26.	−65 57	204 27	Direct.	−80 39·4	N. by W.	+85	−35	−79 49	−79 39	Sailing amongst ice, very steady.
			Direct.	−80 31·5	N.W. ¾ W.	+61	−35	−80 06		
			Direct.	−78 21·3	S.E.	−51	−35	−79 47		
			Direct.	−78 39·0	E.S.E.	−18	−35	−79 32		
27.	−66 08	203 50	Direct.	−78 44·5	E.S.E.	−18	−35	−79 37		
			Direct.	−79 00·2	E. by S.	− 1	−35	−79 36		
			Def. N.	−77 37·7	E.S.E.	−18	−81	−79 17		
			Def. S.	−78 30·0	E.S.E.	−18	−35	−79 23		
			Direct.	−80 38·3	N.W. by N.	+75	−35	−79 58	−79 39	Sailing amongst ice, very steady.

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* The result is omitted in the mean, as it differs so widely from all others of the same period.

Observations of Inclination. (Continued.)

1841.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Dec. 27.	−66° 08′	203° 50′	Mag. N.	−80° 16′·1	N.W. by N.	+75′	−35′	−79° 36′	−79° 39′	Sailing amongst ice, very steady.
			Mag. N.S.	−79 58·1	N.W. by N.	+75	−35	−79 18		
			Mag. S.	−80 34·0	N.W. by N.	+75	−35	−79 54		
			Direct.	−78 03·0	S. by E.	−83	−35	−80 01		
			Direct.	−78 21·3	S.E.	−52	−35	−79 48		
28.	−66 10	202 54	Direct.	−80 00·0	W. by N.	+32	−35	−80 03	−80 01	Sailing amongst ice, very steady.
			Def. N.	−78 52·8	W. by N.	+32	−81	−79 42		
	−66 11	202 54	Direct.	−80 50·2	N. ½ W.	+85	−35	−80 00		
			Direct.	−78 29·2	S.W. by S.	−65	−35	−80 09		
29.	−66 20	203 20	Direct.	−79 22·8	E.	+16	−35	−79 42		
			Direct.	−80 44·3	N.W. ½ W.	+64	−35	−80 15		
			Direct.	−80 47·6	N.W.	+69	−35	−80 14		
			Direct.	−79 26·8	E. ½ N.	+24	−35	−79 38		
30.	−66 25	203 12	Direct.	−79 24·7	E. by S.	0	−35	−80 00		
			Direct.	−81 13·2	N. W. by N.	+75	−35	−80 33		
			Direct.	−79 45·3	E.	+16	−35	−80 04		
			Direct.	−79 59·8	E. by N.	+32	−35	−80 03		
			Direct.	−80 09·2	E.N.E.	+46	−35	−79 58		
			Direct.	−80 14·0	N.E. by E. ½ E.	+52	−35	−79 57		
31.	−66 30	203 08	Direct.	−81 15·6	N. by W.	+85	−35	−80 26		Fast to a piece of ice: Erebus fast to the same piece distant fifty yards. Terror's head to North*.
			Direct.	−81 17·6	N. ½ W.	+85	−35	−80 28		
			Direct.	−81 15·5	N.	+86	−35	−80 25		
			Direct.	−81 10·2	N. ½ E	+85	−35	−80 20		
			Direct.	−81 11·8	N. by E.	+85	−35	−80 22		Erebus bearing E.
			Direct.	−80 28·6	W. ½ N.	+24	−35	−80 40		Ditto; Erebus N.
1842. Jan. 1.	−66 36	203 29	Direct.	−81 14·8	N.W. ½ W.	+64	−35	−80 46		Ditto; Erebus N.E.
			Def. N.	−80 22·2	N.W. ½ W.	+64	−81	−80 39		
			Def. S.	−81 06·3	N.W. ½ W.	+64	−35	−80 37		
			Mag. N.	−81 03·7	N.W. ½ W.	+64	−35	−80 34		
			Mag. N.S.	−80 50·7	N.W. ½ W.	+64	−35	−80 22		
			Mag. S.	−81 01·3	N.W. ½ W.	+64	−35	−80 32		
			Direct.	−81 15·4	N.W. ½ W.	+64	−35	−80 46		
2.	−66 36	203 14	Direct.	−81 12·4	N. ½ W.	+85	−35	−80 22		Ditto; Erebus E.
3.	−66 32	203 23	Direct.	−78 46·1	S.E.	−52	−35	−80 13	−80 03	Running amongst loose ice, very steady.
			Direct.	−78 26·1	S. by W.	−83	−35	−80 24		
			Direct.	−78 29·6	S. by W. ½ W.	−80	−35	−80 25		
5.	−66 14	203 17	Direct.	−79 36·7	E. ½ S.	+ 8	−35	−80 04		
6.	−66 09	203 58	Direct.	−77 46·2	S. ¾ W.	−83	−35	−79 44		
			Direct.	−80 15·8	N. ¾ E.	+85	−35	−79 26		
7.	−66 20	203 39	Direct.	−80 31·9	N.W.	+69	−35	−79 58	−79 52	Running amongst loose ice, very steady.
			Def. N.	−79 32·1	N.W.	+69	−81	−79 44		
			Def. S.	−80 26·2	N.W.	+69	−35	−79 52		
			Mag. N.	−80 15·7	N.W.	+69	−35	−79 42		
			Mag. N.S.	−80 05·8	N.W.	+69	−35	−79 32		
			Mag. S.	−80 34·5	N.W.	+69	−35	−80 01		
			Direct.	−80 37·9	N.W.	+69	−35	−80 04		
			Direct.	−79 53·0	S.	−85	−35	−79 53		
			Direct.	−78 00·9	S. by E.	−83	−35	−79 59		
8.	−66 05	204 02	Direct.	−78 15·2	S. by W. ½ W.	−80	−35	−80 10	−79 51	Running amongst loose ice, very steady.
			Direct.	−80 44·1	N.	+86	−35	−79 53		
			Def. N.	−79 45·4	N.	+86	−81	−79 40		
			Def. S.	−80 41·6	N.	+86	−35	−79 51		
			Mag. N.	−80 27·8	N.	+86	−35	−79 37		

* These observations are omitted in the general table of results, and in the map: the proximity of the two ships appears however to have produced scarcely any sensible effect on the inclination needle.

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Jan. 8.	−66° 05′	204° 02′	Mag. N.S.	−80° 20′·7	N.	+86′	−35′	−79° 30′	−79° 51′	Running amongst loose ice, very steady.
			Mag. S.	−80 46·2	N.	+86	−35	−79 55		
			Direct.	−80 45·4	N.	+86	−35	−79 54		
			Direct.	−78 00·6	S. by E.	−83	−35	−79 59		
			Direct.	−78 25·8	S.W. by S.	−65	−35	−80 06		
			Direct.	−80 40·4	N. by W.	+85	−35	−79 50		
			Direct.	−80 43·1	N.	+86	−35	−79 52		
			Direct.	−79 10·0	E. ½ S.	+ 8	−35	−79 37		
			Direct.	−77 56·0	S.	−85	−35	−79 56		
9.	−66 01	204 04	Direct.	−78 58·2	E. by S.	− 1	−35	−79 34	−79 50	Running amongst loose ice, very steady.
			Direct.	−79 22·2	E. ¼ N.	+20	−35	−79 37		
			Direct.	−78 46·0	S.W. by W.	−36	−35	−79 57		
			Direct.	−78 33·8	S.W. ½ W.	−44	−35	−79 53		
			Def. N.	−77 34·8	S.W. ½ W.	−44	−81	−79 40		
			Direct.	−78 36·3	S.W.	−52	−35	−80 03		
			Direct.	−79 00·8	W.S.W.	−18	−35	−79 54		
			Def. S.	−79 10·9	W.S.W.	−18	−35	−80 04		
			Mag. N.	−78 28·8	S.W. by W.	−36	−35	−79 40		
			Mag. N.S.	−78 24·4	S.W. by W.	−36	−35	−79 35		
			Mag. S.	−78 48·6	S.W. by W.	−36	−35	−80 00		
			Direct.	−78 45·2	S.W. by W.	−36	−35	−79 56		
10.	−65 57	203 56	Direct.	−79 03·7	W.S.W.	−18	−35	−79 57	−79 47	
			Direct.	−79 30·4	W. by S.	− 1	−35	−80 06		
			Def. N.	−78 23·7	W. by S.	− 1	−81	−79 46		
			Def. S.	−79 14·9	W. by S.	− 1	−35	−79 51		
			Mag. N.	−79 17·4	W. by S.	− 1	−35	−79 53		
			Direct.	−79 15·1	E.	+16	−35	−79 34		
			Mag. S.	−79 17·6	E.	+16	−35	−79 37		
			Mag. N.S.	−78 55·2	E.	+16	−35	−79 14		
			Direct.	−79 15·7	E.	+16	−35	−79 35		
			Direct.	−78 29·0	S.E. by E. ½ E.	−27	−35	−79 31		
			Direct.	−79 41·5	W. ¼ S.	+12	−35	−80 05		
			Direct.	−79 23·8	W. by S. ½ S.	− 8	−35	−80 07		
	−65 58	203 37	Direct.	−78 44·5	S.W. by W.	−36	−35	−79 55		
			Direct.	−78 46·3	S.W. by W.	−36	−35	−79 57		
11.	−65 56	203 31	Direct.	−77 58·3	S. by E.	−83	−35	−79 56	−79 51	Very steady, working about in a hole of water.
			Direct.	−77 53·2	S.	−85	−35	−79 53		
			Def. N.	−76 51·8	S.	−85	−81	−79 58		
			Def. S.	−77 56·7	S.	−85	−35	−79 57		
			Mag. N.	−77 31·0	S.	−85	−35	−79 31		
			Mag. N.S.	−77 35·4	S.	−85	−35	−79 35		
			Mag. S.	−77 49·3	S.	−85	−35	−79 49		
12.	−65 45	203 23	Direct.	−78 30·4	S.W.	−52	−35	−79 57		
			Direct.	−78 20·6	S.W. by S.	−65	−35	−80 01		
			Direct.	−78 44·4	S.W. by W.	−36	−35	−79 55		
13.	−66 06	202 10	Direct.	−78 13·7	S. by W.	−82	−35	−80 11	−79 48	
			Direct.	−77 50·3	S.	−84	−35	−79 49		
	−66 12	202 12	Direct.	−80 22·0	N.N.E.	+81	−35	−79 36		
			Direct.	−80 46·2	N.	+86	−35	−79 55		
			Direct.	−80 38·4	N. ½ E.	+85	−35	−79 48		
			Def. N.	−79 44·5	N. ½ E.	+85	−81	−79 41		
			Def. S.	−80 39·1	N. ½ E.	+85	−35	−79 49		
			Mag. N.	−80 22·8	N. ½ E.	+85	−35	−79 33		
			Mag. N.S.	−80 20·0	N. ½ E.	+85	−35	−79 30		
			Mag. S.	−80 37·4	N. ½ E.	+85	−35	−79 47		
			Direct.	−80 39·8	N. ½ E.	+85	−35	−79 50		
			Direct.	−78 07·0	S.S.E.	−77	−35	−79 59		
			Direct.	−77 58·2	S.	−85	−35	−79 58		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections. Ship's attraction.	Corrections. Index.	True Inclination.		Remarks.
	° ′	° ′		° ′		′	′	° ′	° ′	
Jan. 14.	−66 08	201 46	Direct.	−77 58·8	S.	−85	−35	−79 59	−79 35	Very steady, working about in a hole of water.
			Direct.	−78 09·0	S. by .E	−83	−35	−80 07		
			Direct.	−80 23·5	N.N.E.	+81	−35	−79 38		
			Direct.	−80 20·4	N.E.	+69	−35	−79 46		
			Direct.	−79 51·7	N.E. by E.	+59	−35	−79 28		
			Def. N.	−79 01·7	N.E. by E.	+59	−81	−79 24		
			Def. S.	−80 00·4	N.E. by E.	+59	−35	−79 36		
			Mag. N.	−79 39·7	N.E. by E.	+59	−35	−79 16		
			Mag. N.S.	−79 28·8	N.E. by E.	+59	−35	−79 05		
			Mag. S.	−80 17·5	N.N.E.	+81	−35	−79 32		
			Direct.	−80 22·0	N.N.E.	+81	−35	−79 36		
15.	−65 59	202 22	Direct.	−78 45·5	E.S.E.	−18	−35	−79 39	−79 38	
	−65 58	202 21	Direct.	−79 19·4	E.	+16	−35	−79 38		
			Direct.	−78 31·4	S.W. by S.	−65	−35	−80 11		
			Direct.	−78 45·9	E.S.E.	−18	−35	−79 39		
16.	−65 47	202 08	Direct.	−79 23·8	E.	+16	−35	−79 43		
			Def. N.	−78 32·3	E.	+16	−81	−79 37		
			Def. S.	−79 13·2	E.	+16	−35	−79 32		
			Mag. N.	−79 06·4	E.	+16	−35	−79 25		
			Mag. N.S.	−79 00·0	E.	+16	−35	−79 19		
			Mag. S.	−79 19·3	E.	+16	−35	−79 38		
			Direct.	−79 23·4	E.	+16	−35	−79 42		
			Direct.	−79 25·3	E.	+16	−35	−79 44		
17.	−65 47	201 56	Direct.	−80 05·9	N.E.	+69	−35	−79 32		Fast to a piece of ice.
19.	−66 11	200 45	Direct.	−80 55·9	N.	+86	−35	−80 05	−80 22	Ship steady.
			Direct.	−80 50·3	N. by E. ¾E.	+82	−35	−80 03		
			Direct.	−78 47·2	S.S.W. ½ W.	−71	−35	−80 33		
20.	−67 37	200 12	Direct.	−79 51·6	W. by S.	− 1	−35	−80 28		Long swell, ship striking heavily against pieces of ice.
			Direct.	−80 25·6	W. by N.	+32	−35	−80 29		
			Direct.	−80 03·1	W.	+16	−35	−80 22		
			Direct.	−80 47·6	N. by E.	+85	−35	−79 58		
			Direct.	−80 59·8	N. by E. ½ E.	+83	−35	−80 12		
			Direct.	−78 26·8	S. by W.	−83	−35	−80 25		
21.	−66 43	202 50	Direct.	−78 44·7	S.S.W.	−77	−35	−80 37		Swell from W.N.W.
			Direct.	−78 38·3	S. by W.	−83	−35	−80 36		
			Direct.	−78 35·4	S.	−85	−35	−80 35		
26.	−67 12	203 12	Direct.	−80 12·8	E. by N.	+32	−35	−80 16	−80 06*	Both ships made fast to a piece of ice; Erebus N. by W., distant 20 fathoms.
			Def. N.	−79 15·3	E. by N.	+32	−81	−80 04		
			Def. S.	−80 14·2	E. by N.	+32	−35	−80 17		
			Mag. N.	−80 07·4	E. by N.	+32	−35	−80 10		
			Mag. N.S.	−79 55·1	E. by N.	+32	−35	−79 58		
			Direct.	−80 03·0	E.	+16	−35	−80 22		
			Direct.	−78 54·4	S.E. by E.	−36	−35	−80 05		
			Mag. N.S.	−78 23·2	S.E. by E.	−36	−35	−79 34		
			Mag. S.	−78 46·7	S.E. by E.	−36	−35	−79 58		
			Direct.	−79 28·2	E.S.E.	−18	−35	−80 21		
28.	−67 46	204 17	Direct.	−80 38·8	E. by N.	+32	−35	−80 42	−80 43	Swell from W.S.W. Table steady.
			Def. N.	−79 40·5	E. by N.	+32	−81	−80 30		
			Def. S.	−81 31·3	N.	+86	−35	−80 40		
			Direct.	−80 46·1	E.N.E.	+46	−35	−80 35		
			Direct.	−81 45·8	N. by E.	+85	−35	−80 56		
			Def. N.	−81 02·7	N. by E.	+85	−81	−81 07		
			Direct.	−81 31·0	N.N.E.	+81	−35	−80 45		
			Def. N.	−80 43·8	N.N.E.	+81	−81	−80 44		
			Mag. N.	−81 24·4	N.N.E.	+81	−35	−80 38		

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* Omitted in the Map, in consequence of the vicinity of the other ship.

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Jan. 28.	−67° 46′	204° 17′	Mag. N.S.	−81° 16′·6	N.N.E.	+81′	−35′	−80° 31′	−80° 43′	Table steady.
			Mag. S.	−81 25·2	N.N.E.	+81	−35	−80 39		
			Direct.	−79 06·5	S. ¾ W.	−84	−35	−81 06		
			Def. N.	−78 00·0	S. ¾ W.	−84	−81	−80 45		
			Def. S.	−78 38·0	S. ¾ W.	−84	−35	−80 37		
			Mag. N.	−78 36·0	S. ¾ W.	−84	−35	−80 35		
			Mag. N.S.	−78 32·1	S. ¾ W.	−84	−35	−80 31	−80 48	
			Mag. S.	−78 45·8	S. ¾ W.	−84	−35	−80 45		
			Direct.	−79 04·5	S. ¾ W.	−84	−35	−81 04		
			Direct.	−81 39·3	N.	+86	−35	−80 48		
			Direct.	−81 42·2	N. by W. ¾ W.	+83	−35	−80 54		
			Direct.	−81 47·6	N. by W. ½ W.	+84	−35	−81 00		
			Direct.	−78 47·4	S. ½ E.	−84	−35	−80 46		
			Direct.	−78 50·6	S. ½ E.	−84	−35	−80 50		
	−67 48	204 18	Direct.	−79 45·4	S.W. by W.	−36	−35	−80 56		
			Direct.	−80 40·8	W.	+16	−35	−81 00		Very steady.
			Direct.	−81 31·5	N.W. by W.	+59	−35	−81 08		
			Direct.	−80 15·3	E.	+16	−35	−80 34		
			Direct.	−80 01·3	E. by S.	− 1	−35	−80 37		
			Direct.	−79 46·6	E.S.E.	−18	−35	−80 40		
			Direct.	−80 31·9	E. by N.	+32	−35	−80 35		
29.	−67 24	204 05	Direct.	−80 38·5	E.N.E.	+46	−35	−80 28	−80 44	Strong breeze, steady.
			Direct.	−79 10·2	S. by W.	−83	−35	−81 08		
			Def. N.	−78 06·9	S. by W.	−83	−81	−80 51		
			Def. S.	−78 44·1	E.N.E.	+46	−35	*		
			Mag. N.	−78 38·6	E.N.E.	+46	−35			
			Mag. N.S.	−78 33·9	E.N.E.	+46	−35			
31.	−67 12	202 24	Direct.	−78 59·8	S.S.W.	−77	−35	−80 52		
			Def. N.	−78 07·9	S.S.W.	−77	−81	−80 46		
			Def. S.	−78 55·8	S.S.W.	−77	−35	−80 48		
			Mag. N.	−78 36·9	S.S.W.	−77	−35	−80 29		
			Mag. N.S.	−78 29·0	S.S.W.	−77	−35	−80 21		
			Mag. S.	−79 07·7	S.S.W.	−77	−35	−81 00		
			Direct.	−79 23·3	S.W.	−52	−35	−80 50		
			Def. N.	−78 09·4	S.W.	−52	−81	−80 22		
			Direct.	−79 15·3	S.W. by S.	−65	−35	−80 55		
			Def. N.	−78 23·5	S.W. by S.	−65	−81	−80 50		
Feb. 1.	−67 12	201 34	Direct.	−80 15·5	W. by S.	− 1	−35	−80 52	−80 35	Ship steady, ice all around.
			Def. N.	−79 14·5	W. by S.	− 1	−81	−80 37		
			Direct.	−80 06·5	E.	+17	−35	−80 25		
			Def. N.	−79 05·2	E.	+17	−81	−80 09		
			Direct.	−79 29·1	E.S.E.	−18	−35	−80 22		
			Direct.	−80 25·9	W.	+17	−35	−80 44		
			Direct.	−79 51·9	W.S.W.	−18	−35	−80 45		
	−67 16		Direct.	−78 58·6	S.S.W.	−77	−35	−80 51		
			Def. N.	−77 59·0	S.S.W.	−77	−81	−80 31		Table steady.
			Def. S.	−78 53·6	S.S.W.	−77	−35	−80 46		
			Mag. N.	−78 32·1	S.S.W.	−77	−35	−80 24		
			Mag. N.S.	−78 30·2	S.S.W.	−77	−35	−80 22		
			Mag. S.	−78 49·0	S.S.W.	−77	−35	−80 41		
			Direct.	−79 00·8	S.S.W.	−77	−35	−80 53		
			Direct.	−81 30·0	N. ¾ W.	+86	−35	−80 39		
			Def. N.	−80 37·0	N. ¾ W.	+86	−81	−80 32		
			Direct.	−79 08·1	S.W.	−52	−35	−80 35		
			Def. N.	−78 11·1	S.W.	−52	−81	−80 24		

* Omitted in the mean; apparently the degree should have been written 80 instead of 78.

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Feb. 2.	−67° 56′	199° 48′	Direct.	−79° 28′·6	s. by w.	−83′	−35′	−81° 27′	−81° 18′	Table steady.
			Def. N.	−78 37·8	s. by w.	−83	−81	−81 22		
			Def. S.	−79 15·1	s. by w.	−83	−35	−81 13		
			Mag. N.	−78 53·6	s. by w.	−83	−35	−80 52		
			Mag. N.S.	−79 07·5	s. by w.	−83	−35	−81 06		
			Mag. S.	−79 26·9	s. by w.	−83	−35	−81 25		
			Direct.	−79 27·4	s. by w.	−83	−35	−81 25		
3.	−68 21	200 06	Direct.	−79 34·2	s.s.w.	−77	−35	−81 26		
			Def. N.	−78 31·9	s.s.w.	−77	−81	−81 10		
			Def. S.	−79 26·7	s.s.w.	−77	−35	−81 19		
			Mag. N.	−79 24·2	s.s.w.	−77	−35	−81 16		
			Mag. N.S.	−79 23·4	s.s w.	−77	−35	−81 15		
			Mag. S.	−79 28·6	s.s.w.	−77	−35	−81 21		
			Direct.	−79 36·1	s.s.w.	−77	−35	−81 28		
4.	−68 45	199 41	Direct.	−79 32·5	s.	−85	−35	−81 33	−81 33	Fresh breeze, steady.
			Def. N.	−78 50·3	s.	−85	−81	−81 36		
			Def. S.	−79 36·6	s.	−85	−35	−81 37		
			Mag. N.	−79 17·2	s.	−85	−35	−81 17		
			Mag. N.S.	−79 12·4	s.	−85	−35	−81 12		
			Mag. S.	−79 43·4	s.	−85	−35	−81 43		
			Direct.	−79 32·1	s. by E.	−83	−35	−81 30		
			Def. N.	−78 50·4	s. by E.	−83	−81	−81 34		
			Def. S.	−79 25·8	s. by E.	−83	−35	−81 24		
	−68 49	199 26	Direct.	−82 31·4	N.N.W.	+82	−35	−81 44		
			Def. N.	−81 48·7	N.N.W.	+82	−81	−81 48		
5.	−68 52	198 24	Direct.	−81 51·5	s.w.	−52	−35	−83 19	−82 30	
			Def. N.	−79 59·5	s.w.	−52	−81	−82 13		
			Def. S.	−80 58·7	s.w.	−52	−35	−82 26		
			Mag. N.	−80 48·0	s.w.	−52	−35	−82 15		
			Mag. N.S.	−80 36·8	s.w.	−52	−35	−82 04		
			Mag. S.	−81 04·1	s.w.	−52	−35	−82 31		
			Direct.	−81 21·6	s.w. ½ w.	−44	−35	−82 41		
			Direct.	−81 20·0	s.w. by w.	−36	−35	−82 31		
6.	−69 55	192 17	Direct.	−81 09·2	s. by w.	−84	−35	−83 08	−83 00	Steering well, but table not steady.
			Def. N.	−80 15·1	s. by w.	−84	−81	−83 00		
			Def. S.	−81 04·2	s. by w.	−84	−35	−83 03		
			Mag. N.	−80 52·3	s. by w.	−84	−35	−82 51		
			Mag. N.S.	−80 39·1	s. by w.	−84	−35	−82 38		
			Mag. S.	−81 09·2	s. by w.	−84	−35	−83 08		
			Direct.	−81 12·8	s. by w.	−84	−35	−83 12		
			Direct.	−80 56·9	s.	−86	−35	−82 58		
			Def. N	−80 00·2	s.	−86	−81	−82 47		
			Direct.	−81 12·6	s. by w.	−84	−35	−83 12		
7.	−70 05	191 03	Direct.	−81 35·1	s.s.w.	−78	−35	−83 28	−83 20	Strong breeze, ship steering wildly.
			Def. N.	−80 38·2	s.s.w.	−78	−81	−83 17		
			Direct.	−81 56·4	s.w.	−52	−35	−83 23		
			Direct.	−81 35·3	s. by w. ¾ w.	−80	−35	−83 30		
			Def. S.	−81 20·0	s.s.w.	−78	−35	−83 13		
			Mag. N.	−81 24·7	s.s.w.	−78	−35	−83 18		
			Mag. N.S.	−81 15 6	s.s.w.	−78	−35	−83 09		
			Mag. S.	−81 23·9	s.s.w.	−78	−35	−83 17		
			Direct.	−81 29 6	s. by w. ½ w	−81	−35	−83 26		
8.	−70 08	186 39	Direct.	−81 56·9	s.w.	−52	−35	−83 24	−83 23	Table steady.
			Def. N.	−81 16·7	s.w.	−52	−81	−83 30		
			Direct.	−82 12·3	s.w. by w.	−36	−35	−83 23		
			Def. N.	−81 34·1	s.w. by w.	−36	−83	−83 31		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Feb. 8.	−70° 08′	186° 39′	Def. S.	−82° 09′·9	s.w. by w.	−36′	−35′	−83° 21′	−83° 23′	Table steady.
			Mag. N.	−82 10·1	s.w. by w.	−36	−35	−83 21		
			Mag. N.S.	−82 03·7	s.w. by w.	−36	−35	−83 15		
			Mag. S.	−82 10·3	s.w. by w.	−36	−35	−83 21		
			Direct.	−82 15·9	s.w. by w.	−36	−35	−83 27		
			Direct.	−81 19·7	s.	−87	−35	−83 22		
	−70 17	186 04	Direct.	−81 16·1	s.	−87	−35	−83 18		
			Def. N.	−80 37·6	s.	−87	−81	−83 26		
			Def. S.	−81 38·5	s.	−87	−35	−83 41		
			Mag. N.	−81 11·6	s.	−87	−35	−83 14		
			Mag. N.S.	−81 04·5	s.	−87	−35	−83 07		
			Mag. S.	−81 33·4	s.	−87	−35	−83 35		
			Direct.	−81 20·6	s.	−87	−35	−83 23		
9.	−70 32	185 38	Direct.	−83 51·8	w. by n.	+32	−35	−83 55	−83 30	Head swell, unsteady.
			Def. N.	−83 09·4	w. by n.	+32	−81	−83 58		
			Def. S.	−83 55·8	w. by n.	+32	−35	−83 59		
			Mag. N.S.	−83 36·2	w. by n.	+32	−35	−83 39		
			Direct.	−82 08·5	w. by n.	+32	−35	−82 12		
			Def. N.	−81 14·8	w. by n.	+32	−81	−82 04		
			Direct.	−82 02·7	s.e. ½ s.	−59	−35	−83 37		
			Def. S.	−82 01·0	s.e. ½ s.	−59	−35	−83 35		
			Mag. N.S.	−82 03·5	s.e. ½ s.	−59	−35	−83 38		
			Direct.	−82 12 6	s.e. by s.	−66	−35	−83 54		
10.	−69 56	184 43	Direct.	−83 33·0	w. by s.	− 1	−35	−84 09	−84 03	Heavy swell, unsteady.
			Def. N.	−82 37·3	w. by s.	− 1	−81	−83 59		
			Def. S.	−83 31·5	w. by s.	− 1	−35	−84 07		
			Mag. N.	−83 25·9	w. by s.	− 1	−35	−84 02		
			Mag. N.S.	−83 11·0	w. by s.	− 1	−35	−83 47		
			Mag. S.	−83 33·1	w. by s.	− 1	−35	−84 09		
			Direct.	−83 34·2	w. by s.	− 1	−35	−84 10		
			Direct.	−83 46·2	w.	+17	−35	−84 04		
11.	−69 51	183 02	Direct.	−83 21·8	w.s.w.	−18	−35	−84 15	−84 09	Strong wind, westerly swell, ship unsteady.
			Def. N.	−82 21·1	w.s.w.	−18	−81	−84 00		
			Def. S.	−83 04·0	w.s.w.	−18	−35	−83 57		
			Mag. N.	−83 25·7	w.s.w.	−18	−35	−84 19		
			Mag. N.S.	−82 58·0	w.s.w.	−18	−35	−83 51		
			Mag. S.	−83 20·5	w.s.w.	−18	−35	−84 14		
	−70 03	181 44	Direct.	−82 45·0	s.w. by s.	−66	−35	−84 26		
12.	−71 03	180 56	Direct.	−82 46·6	s.e. by s.	−66	−35	−84 28	−84 20	Cross sea, table very unsteady.
			Def. N.	−81 48·5	s.e. by s.	−66	−81	−84 16		
			Def. S.	−82 39·3	s.e. by s.	−66	−35	−84 20		
			Mag. N.	−82 24·9	s.e. by s.	−66	−35	−84 06		
			Mag. N.S.	−82 21·1	s.e. by s.	−66	−35	−84 02		
			Mag. S.	−82 34·9	s.e. by s.	−66	−35	−84 16		
			Direct.	−82 45·2	s.e. by s.	−66	−35	−84 26		Table very unsteady, a cross sea.
	−71 02	180 58	Direct.	−83 08·2	s.e. by s.	−66	−35	−84 49		
13.	−72 07	181 50	Direct.	−83 16·8	s.e. by s.	−66	−35	−84 58	−84 59	A swell from N.W., ship unsteady, steering badly.
			Def. N.	−82 21·1	s.e. by s.	−66	−81	−84 48		
			Def. S.	−83 18·6	s.e. by s.	−66	−35	−85 00		
			Mag. N.	−83 06·9	s.e. by s.	−66	−35	−84 48		
			Mag. N.S.	−82 55·3	s.e. by s.	−66	−35	−84 36		
			Mag. S.	−83 17·7	s.e. by s.	−66	−35	−84 59		
			Direct.	−83 20·2	s.e. by s.	−66	−35	−85 01		
			Direct.	−83 37·9	s.e. by s.	−66	−35	−85 19		
			Direct.	−83 40·5	s.e. by s.	−66	−35	−85 22		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Feb. 14.	−72 55	181 33	Direct.	−83 58·2	S.E. by E.	−36	−35	−85 09	−85 22	A swell from the W.N.W., unsteady.
			Def. N.	−83 21·7	S.E. by E.	−36	−81	−85 19		
			Def. S.	−84 07·0	S.E. by E.	−36	−35	−85 18		
			Mag. N.	−84 01·7	S.E. by E.	−36	−35	−85 13		
			Mag. N.S.	−83 29·5	S.E. by E.	−36	−35	−84 40		
			Mag. S.	−83 58·4	S.E. by E.	−36	−35	−85 09		
			Direct.	−84 00·6	S.E. by E.	−36	−35	−85 12		
	−73 23	181 11	Direct.	−84 16·8	S.E.	−52	−35	−85 44		Strong breeze, unsteady.
15.	−74 20	177 55	Direct.	−84 51·4	S.E. by S.	−66	−35	−86 32		Heavy sea, very unsteady.
16.	−74 51	174 02	Direct.	−85 13·4	S.S.E.	−79	−35	−87 07	−87 05	
			Def. N.	−84 17·5	S.S.E.	−79	−81	−86 58		Table steady.
			Def. S.	−85 10·6	S.S.E.	−79	−35	−87 05		
			Mag. N.	−85 08·8	S.S.E.	−79	−35	−87 03		
			Mag. N.S.	−84 53·3	S.S.E.	−79	−35	−86 47		
			Mag. S.	−85 12·0	S.S.E.	−79	−35	−87 06		
			Direct.	−85 15·6	S.S.E.	−79	−35	−87 10		
	−75 05	173 10	Direct.	−85 49·1	S.E.	−52	−35	−87 16		
	−75 09	173 16	Direct.	−86 56·1	E. $\frac{1}{2}$ S.	+ 7	−35	−87 24		N.W. swell, slight motion.
			Direct.	−86 33·0	E. by S.	− 2	−35	−87 10		
			Def. N.	−85 35·9	E. by S.	− 2	−81	−86 59		
			Def. S.	−86 39·6	E. by S.	− 2	−35	−87 17		
			Mag. N.S.	−86 13·2	E. by S.	− 2	−35	−86 50		
17.	−75 57	175 08	Direct.	−87 15·8	E.N.E.	+46	−35	−87 05	−87 03	Very unsteady, steering badly.
	−76 06	174 57	Direct.	−87 12·6	E. by N. $\frac{1}{2}$ N.	+39	−35	−87 09		
			Def. N.	−86 31·1	E. by N. $\frac{1}{2}$ N.	+39	−81	−87 13		
			Def. S.	−87 05·2	E. by N. $\frac{1}{2}$ N.	+39	−35	−87 01		
			Mag. N.	−86 50·8	E. by N. $\frac{1}{2}$ N.	+39	−35	−86 47		
			Mag. N.S.	−86 39·4	E. by N. $\frac{1}{2}$ N.	+39	−35	−86 35		
			Mag. S.	−87 33·9	E. by N. $\frac{1}{2}$ N.	+39	−35	−87 30		
			Direct.	−87 08·0	E. by N. $\frac{1}{2}$ N.	+39	−35	−87 04		
18.	−77 02	181 37	Direct.	−87 06·3	E.N.E.	+46	−35	−86 55	−86 56	Cross sea, table unsteady.
			Def. N.	−86 16·8	E.N.E.	+46	−81	−86 52		
			Def. S.	−87 21·3	E.N.E.	+46	−35	−87 10		
			Mag. N.	−87 14·9	E.N.E.	+46	−35	−87 04		
			Mag. N.S.	−86 45·6	E.N.E.	+46	−35	−86 35		
			Mag. S.	−87 15·2	E.N.E.	+46	−35	−87 04		
			Direct.	−87 37·4	N.E. $\frac{1}{2}$ E.	+64	−35	−87 08		
	−77 09	181 22	Direct.	−86 56·5	N.E. by E. $\frac{1}{2}$ E.	+52	−35	−86 39		
19.	−76 48	184 46	Direct.	−87 27·6	N. by E.	+88	−35	−86 35	−86 30	
			Def. N.	−86 54·2	N. by E.	+88	−81	−86 47		
			Def. S.	−87 45·2	N. by E.	+88	−35	−86 52		
			Mag. N.	−87 16·6	N. by E.	+88	−35	−86 24		
			Mag. N.S.	−87 15·1	N. by E.	+88	−35	−86 22		
			Mag. S.	−86 53·6	N. by E.	+88	−35	−86 01		
			Direct.	−87 29·1	N. by E.	+88	−35	−86 36		
	−76 50	186 21	Direct.	−87 01·3	N.E. $\frac{1}{2}$ N.	+72	−35	−86 24		
20.	−76 20	190 26	Direct.	−86 44·6	N.E.	+69	−35	−86 11	−85 59	
			Def. N.	−86 04·7	N.E.	+69	−81	−86 17		
			Def. S.	−86 42·3	N.E.	+69	−35	−86 08		
			Mag. N.	−86 26·7	N.E.	+69	−35	−85 53		
			Mag. N.S.	−86 23·0	N.E.	+69	−35	−85 49		
			Mag. S.	−86 48·5	N.E.	+69	−35	−86 15		
			Direct.	−86 39·1	N.E.	+69	−35	−86 05		
	−76 14	192 29	Direct.	−85 56·9	N.E. by E.	+59	−35	−85 33		Strong gale, heavy sea, a great deal of motion.
21.	−75 45	195 02	Direct.	−84 13·7	S.W.	−52	−35	−85 41		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° '	° '		° '		'	'	° '	° '	
Feb. 22.	−76 24	184 54	Direct.	−83 41·5	s.e. by s.	−66	−35	−85 23	−85 12	A head sea, ship unsteady.
			Def. N.	−82 56·0	s.e. by s.	−66	−81	−85 23		
			Def. S.	−83 37·0	s.e. by s.	−66	−35	−85 18		
			Mag. N.	−83 19·8	s.e. by s.	−66	−35	−85 01		
			Mag. N.S.	−82 59·8	s.e. by s.	−66	−35	−84 41		
			Mag. S.	−83 29·9	s.e. by s.	−66	−35	−85 11		
			Direct.	−83 45·2	s.e. by s.	−66	−35	−85 26		
	−76 46	193 48	Direct.	−84 19·4	e.s.e.	−18	−35	−85 12		
	−77 13	193 52	Direct.	−84 37·4	e. by s.	− 1	−35	−85 13		Light swell, gentle motion.
			Def. N.	−83 51·4	e. by s.	− 1	−81	−85 13		
			Def. S.	−84 50·8	e. by s.	− 1	−35	−85 27		
			Mag. N.	−84 31·6	e. by s.	− 1	−35	−85 08		
			Mag. N.S.	−84 17·0	e. by s.	− 1	−35	−84 53		
			Mag. S.	−84 27·8	e. by s.	− 1	−35	−85 04		
			Direct.	−85 02·7	e.	+17	−35	−85 21		
23.	−77 48	197 23	Direct.	−84 14·6	s.w.by w.½ w.	−27	−35	−85 17	−84 49	Table very steady.
	−77 47	197 25	Direct.	−85 13·0	n.e. by e.	+59	−35	−84 49		
			Def. N.	−84 34·3	n.e. by e.	+59	−81	−84 56		
			Def. S.	−85 21·1	n.e. by e.	+59	−35	−84 57		
			Direct.	−85 05·7	e.n.e.	+46	−35	−84 55		
			Mag. N.	−84 21·4	e.n.e.	+46	−35	−84 10		
			Mag. N.S.	−84 41·7	e.n.e.	+46	−35	−84 31		
			Mag. S	−85 00·2	e.n.e.	+46	−35	−84 49		
			Direct.	−85 05·5	e.n.e.	+46	−35	−84 55		
24.	−77 14	199 29	Direct.	−84 00·0	s.w. by s.	−66	−35	−85 41	−85 35	Swell from N.E., steady.
			Def. N.	−83 17·5	s.w. by s.	−66	−81	−85 45		
			Def. S.	−83 57·7	s.w. by s.	−66	−35	−85 39		
			Mag. N.	−83 42·9	s.w. by s.	−66	−35	−85 24		
			Mag. N.S.	−83 32·3	s.w. by s.	−66	−35	−85 13		
			Mag. S.	−84 11·7	s.w. by s.	−66	−35	−85 53		
			Direct.	−85 13·3	w.	+17	−35	−85 31		
	−77 00	198 50	Direct.	−84 25·8	s.w. by w.	−36	−35	−85 37		
25.	−75 20	194 36	Direct.	−85 30·9	w.	+17	−35	−85 49	−85 46	Swell from the E.N.E., steady.
			Def. N.	−84 33·1	w.	+17	−81	−85 37		
			Def. S.	−85 28·4	w.	+17	−35	−85 46		
			Mag. N.	−85 15·5	w.	+17	−35	−85 34		
			Mag. N.S.	−84 59·3	w.	+17	−35	−85 17		
			Mag. S.	−85 22·7	w.	+17	−35	−85 41		
			Direct.	−85 38·6	w.	+17	−35	−85 57		
			Direct.	−84 34·6	s.w. by s.	−66	−35	−86 16		
			Direct.	−86 03·9	w.n.w.	+46	−35	−85 53		
26.	−73 10	189 21	Direct.	−85 37·4	n.w. by w.	+60	−35	−85 12	−85 08	Strong breeze, motion great.
			Def. N.	−84 44·0	n.w. by w.	+60	−81	−85 05		
			Def. S.	−85 36·9	n.w. by w.	+60	−35	−85 12		
			Mag. N.	−85 19·6	n.w. by w.	+60	−35	−84 55		
			Mag. N.S.	−85 37·8	n.w. by w.	+60	−35	−85 13		
			Mag. S.	−85 30·6	n.w. by w.	+60	−35	−85 06		
			Direct.	−85 35·6	n.w. by w.	+60	−35	−85 11		
27.	−72 03	187 40	Direct.	−83 30·8	s.w.	−52	−35	−84 58	−84 56	Swell from the eastward, motion slight.
			Def. N.	−82 37·6	s w.	−52	−81	−84 51		
			Def. S.	−83 36·5	s.w.	−52	−35	−85 04		
			Mag. N.	−83 07·6	s.w.	−52	−35	−84 35		
			Direct.	−84 56·8	w. by n. ½ n.	+39	−35	−84 53		
			Mag. N.S.	−84 25·5	w. by n. ½ n.	+39	−35	−84 22		
			Mag. S.	−83 43·4	s.w.	−52	−35	−85 10		
			Direct.	−83 52·3	w.s.w.	−18	−35	−84 45		
	−71 43	187 15	Direct.	−84 56·8	w.s.w.	−18	−35	−85 50		Table steady.

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Feb. 28.	−71° 20′	184° 30′	Direct.	−84° 01′·9	W. by S.	− 1′	−35′	−84° 38′	° ′	
			Def. N.	−82 59·6	W. by S.	− 1	−81	−84 22		
			Def. S.	−83 56·9	W. by S.	− 1	−35	−84 33		
			Mag. N.	−83 37·9	W. by S.	− 1	−35	−84 14		
			Mag. N.S.	−83 23·9	W. by S.	− 1	−35	−84 00		
			Mag. S.	−84 00·7	W. by S.	− 1	−35	−84 37	−84 37	Table steady.
			Direct.	−83 35·3	S.W. by W.	− 36	−35	−84 46		
	−70 55	183 56	Direct.	−84 32·0	W. ½ S.	+ 8	−35	−84 59		
			Direct.	−84 36·8	W.	+ 17	−35	−84 55		
	−70 49	183 46	Direct.	−85 31·6	N.W. ½ W.	+ 64	−35	−85 03		
Mar. 1.	−69 54	179 55	Direct.	−85 00·0	W.N.W.	+ 54	−35	−84 41		
			Def. N.	−84 06·3	W.N.W.	+ 54	−81	−84 33		
			Def. S.	−84 54·4	W.N.W.	+ 54	−35	−84 35		
			Mag. N.	−84 44·4	W.N.W.	+ 54	−35	−84 25	−84 30	Swell from the eastward, table steady.
			Mag. N.S.	−84 35·4	W.N.W.	+ 54	−35	−84 16		
			Mag. S.	−84 44·7	W.N.W.	+ 54	−35	−84 26		
			Direct.	−84 54·2	W.N.W.	+ 54	−35	−84 35		
			Direct.	−84 28·0	W. by N.	+ 37	−35	−84 26		
2.	−68 09	183 10	Direct.	−83 45·8	N.N.E.	+ 99	−35	−82 42		
			Def. N.	−82 29·8	N.N.E.	+ 99	−81	−82 12		
			Def. S.	−83 33·2	N.N.E.	+ 99	−35	−82 29		
			Mag. N.	−83 31·2	N.N.E.	+ 99	−35	−82 27	−82 26	Table steady.
			Mag. N.S.	−83 17·5	N.N.E.	+ 99	−35	−82 14		
			Mag. S.	−83 26·9	N.N.E.	+ 99	−35	−82 23		
			Direct.	−83 40·9	N.N.E.	+ 99	−35	−82 37		
3.	−67 35	185 18	Direct.	−82 27·4	N.E. by E.	+ 71	−35	−81 51		
			Direct.	−82 53·4	N.E.	+ 83	−35	−82 05		
			Direct.	−82 21·8	N.E. by E.	+ 71	−35	−81 46		
			Def. N.	−81 31·3	N.E. by E.	+ 71	−81	−81 41		
			Def. S.	−82 16·9	N.E. by E.	+ 71	−35	−81 41		Cross sea, unsteady.
			Mag. N.	−82 04·0	N.E. by E.	+ 71	−35	−81 28		
			Mag. N.S.	−81 58·7	N.E. by E.	+ 71	−35	−81 23		
			Mag. S.	−82 02·7	N.E. by E.	+ 71	−35	−81 27	−81 33	
			Direct.	−82 28·2	N.E. ½ E.	+ 76	−35	−81 52		
	−67 27	185 32	Direct.	−82 12·6	W.	+ 18	−35	−82 30		
4.	−67 40	187 40	Direct.	−82 18·4	N. by W.	+103	−35	−81 10		
			Def. N.	−81 14·9	N. by W.	+103	−81	−80 53		
			Def. S.	−82 28·2	N. by W.	+103	−35	−81 20		Strong gale, heavy sea, very unsteady.
			Mag. N.	−82 07·0	N. by W.	+103	−81	−80 59		
			Mag. S.	−82 22·0	N. by W.	+103	−35	−81 14		
5.	−67 09	188 02	Direct.	−82 13·3	N.	+104	−35	−81 04		
			Def. N.	−81 40·1	N.	+104	−81	−81 17		
			Def. S.	−81 45·6	N.	+104	−35	−80 37		
			Mag. N.	−82 19·7	N.	+104	−35	−81 11	−81 03	Heavy sea, very unsteady.
			Mag. N.S.	−82 01·2	N.	+104	−35	−80 52		
			Mag. S.	−82 16·6	N.	+104	−35	−81 08		
			Direct.	−82 20·0	N.	+104	−35	−81 11		
6.	−65 28	191 24	Direct.	−81 09·3	N. by E.	+102	−35	−80 02		
			Def. N.	−80 06·6	N. by E.	+102	−81	−79 46		
			Def. S.	−80 50·1	N. by E.	+102	−35	−79 43		
			Mag. N.	−80 47·0	N. by E.	+102	−35	−79 40		
			Mag. N.S.	−80 34·9	N. by E.	+102	−35	−79 28	−79 42	South-westerly swell, unsteady.
			Mag. S.	−81 00·6	N. by E.	+102	−35	−79 54		
			Direct.	−81 03·5	N. by E.	+102	−35	−79 57		
	−65 04	192 00	Direct.	−80 44·2	N. by E.	+102	−35	−79 37		
	−64 49	192 21	Direct.	−80 28·9	N. by E. ½ E.	+ 99	−35	−79 25		
			Direct.	−80 30·4	N. by E. ½ E.	+ 99	−35	−79 26		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections. Ship's attraction.	Corrections. Index.	True Inclination.		Remarks.
Mar. 7.	−63° 30′	194° 15′	Direct.	−79° 46′·4	N. by E.	+100′	−35′	−78° 41′	−78° 30′	Steady.
			Def. N.	−78 34·4	N. by E.	+100	−81	−78 15		
			Def. S.	−79 29·2	N. by E.	+100	−35	−78 24		
			Mag. N.	−79 26·0	N. by E.	+100	−35	−78 21		
			Mag. N.S.	−79 24·0	N. by E.	+100	−35	−78 19		
			Mag. S.	−79 50·3	N. by E.	+100	−35	−78 45		
			Direct.	−79 49·3	N. by E.	+100	−35	−78 44		
8.	−62 17	195 55	Direct.	−78 44·7	N. by E.	+100	−35	−77 40	−77 30	Steady.
			Def. N.	−77 54·4	N. by E.	+100	−81	−77 35		
			Def. S.	−78 25·8	N. by E.	+100	−35	−77 21		
			Mag. N.	−78 27·8	N. by E.	+100	−35	−77 23		
			Mag. N.S.	−78 20·3	N. by E.	+100	−35	−77 15		
			Mag. S.	−78 42·8	N. by E.	+100	−35	−77 38		
			Direct.	−78 40·3	N. by E.	+100	−35	−77 35		
9.	−61 06	198 08	Direct.	−77 41·6	N.E. ½ N.	+ 85	−35	−76 52	−76 32	Steady.
			Def. N.	−76 24·7	N.E. ½ N.	+ 85	−81	−76 22		
			Def. S.	−77 25·9	N.E. ½ N.	+ 85	−35	−76 36		
			Mag. N.	−77 16·4	N.E. by N.	+ 88	−35	−76 23		
			Direct.	−77 38·4	N.E. by N.	+ 88	−35	−76 45		
			Mag. N.S.	−77 11·9	N.E. by N.	+ 88	−35	−76 19		
			Mag. S.	−77 16·9	N.E. by N.	+ 88	−35	−76 24		
			Direct.	−77 28·6	N.E. by N.	+ 88	−35	−76 36		
			Direct.	−77 16·7	N.E.	+ 81	−35	−76 31		
10.	−60 57	199 03	Direct.	−75 32·7	E.N.E.	+ 53	−35	−75 15	−75 08	Table unsteady.
			Def. N.	−74 41·0	E.N.E.	+ 53	−81	−75 19		
			Def. S.	−75 33·6	E.N.E	+ 53	−35	−75 16		
			Mag. N.	−75 14·2	E.N.E.	+ 53	−35	−74 56		
			Mag. N.S.	−75 08·5	E.N.E.	+ 53	−35	−74 51		
			Mag. S.	−75 27·1	E.N.E.	+ 53	−35	−75 09		
			Direct.	−75 30·9	E.N.E.	+ 53	−35	−75 13		
11.	−60 15	208 06	Direct.	−74 20·6	E. by N.	+ 37	−35	−74 19	−74 21	Strong gale, heavy sea, ship unsteady.
			Def. N.	−73 57·2	E. by N.	+ 37	−81	−74 41		
			Def. S.	−74 16·0	E. by N.	+ 37	−35	−74 14		
			Mag. N.	−74 32·4	E. by N.	+ 37	−35	−74 30		
			Mag. N.S.	−74 16·0	E. by N.	+ 37	−35	−74 14		
			Mag. S.	−74 20·9	E. by N.	+ 37	−35	−74 19		
			Direct.	−74 28·5	E. by N.	+ 37	−35	−74 27		
12.	−60 16	211 45	Direct.	−74 07·4	E. by N.	+ 37	−35	−74 05	−74 14	Heavy swell, ship unsteady.
			Def. N.	−73 31·1	E. by N.	+ 37	−81	−74 15		
			Def. S.	−74 20·5	E. by N.	+ 37	−35	−74 18		
			Mag. N.	−74 08·9	E. by N.	+ 37	−35	−74 07		
			Mag. N.S.	−74 28·0	E. by N.	+ 37	−35	−74 26		
			Mag. S.	−74 33·4	E. by N.	+ 37	−35	−74 31		
			Direct.	−74 11·5	E. by N.	+ 37	−35	−74 09		
	−60 18	212 39	Direct.	−73 59·8	E. by N.	+ 37	−35	−73 58		
13.	−59 53	216 28	Direct.	−74 15·6	N.E. ½ E.	+ 74	−35	−73 37	−73 36	Heavy swell, steering very wildly.
			Def. N.	−73 29·3	N.E. ½ E.	+ 74	−81	−73 36		
			Def. S.	−74 15·9	N.E. ½ E.	+ 74	−35	−73 37		
			Mag. N.	−74 09·7	N.E. ½ E.	+ 74	−35	−73 31		
			Mag. N.S.	−74 15·3	N.E. ½ E.	+ 74	−35	−73 36		
			Mag. S.	−74 16·5	N.E. ½ E.	+ 74	−35	−73 37		
			Direct.	−74 18·2	N.E. ½ E.	+ 74	−35	−73 39		
14.	−59 22	218 14	Direct.	−75 02·4	N.E. by E.	+ 69	−35	−74 28	−73 48	Heavy swell from W.S.W., very unsteady, steering very badly.
			Def. N.	−74 26·8	N.E. by E.	+ 69	−81	−74 39		
			Def. S.	−75 01·0	N.E. by E.	+ 69	−35	−74 27		
			Mag. N.	−74 50·0	N.E. by E.	+ 69	−35	−74 16		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
Mar. 14.	−59° 22′	218° 14′	Mag. N.S.	−74° 58′·0	N.E. by E.	+69′	−35′	−74° 24′	−73° 48′	Heavy swell from W.S.W., very unsteady, steering very badly.
			Mag. S.	−75 01·0	N.E. by E.	+69	−35	−74 27		
			Direct.	−75 09·6	N.E. by E.	+69	−35	−74 36		
			Direct.	−75 07·1	N.E. by E.	+69	−35	−74 33		
			Direct.	−75 13·7	N.E. by E.	+69	−35	−74 40		
15.	−58 49	221 25	Direct.	−73 06·6	E.N.E.	+53	−35	−72 49		
			Def. N.	−72 15·7	E.N.E.	+53	−81	−72 44		
			Def. S.	−73 21·2	F.N.E.	+53	−35	−73 03		
			Mag. N.	−73 08·4	E.N.E.	+53	−35	−72 50		
			Mag. N.S.	−73 13·1	E.N.E.	+53	−35	−72 55		
			Mag. S.	−73 07·7	E.N.E.	+53	−35	−72 50		
			Direct.	−73 10·8	E.N.E.	+53	−35	−72 53		
	−58 48	222 22	Direct.	−74 05·2	E. by N.	+37	−35	−74 03		
16.	−58 59	227 30	Direct.	−73 24·8	E.	+21	−35	−73 39	−73 25	Heavy sea from W.S.W., very unsteady, steering very badly.
	−59 01	227 43	Direct.	−73 21·9	E.	+21	−35	−73 36		
			Def. N.	−72 33·3	E.	+21	−81	−73 30		
			Def. S.	−73 14·1	E.	+21	−35	−73 28		
			Mag. N.	−73 00·4	E.	+21	−35	−73 14		
			Mag. N.S.	−73 09·6	E.	+21	−35	−73 24		
			Mag. S.	−73 07·0	E.	+21	−35	−73 21		
			Direct.	−73 26·6	E.	+21	−35	−73 41		
17.	−59 32	231 46	Direct.	−72 41·3	E.	+21	−35	−72 55		
18.	−60 05	235 56	Direct.	−72 19·5	E. by S.	+ 2	−35	−72 53	−73 01	Heavy sea from W.S.W., very unsteady, steering very badly.
			Def. N.	−71 10·6	E. by S.	+ 2	−81	−72 30		
			Def. S.	−72 24·0	E. by S.	+ 2	−35	−72 57		
			Mag. N.	−72 29·7	E. by S.	+ 2	−35	−73 03		
			Mag. N.S.	−72 04·7	E. by S.	+ 2	−35	−72 38		
			Mag. S.	−72 52·0	E. by S.	+ 2	−35	−73 25		
			Direct.	−73 01·1	E. by N.	+37	−35	−72 59		
	−60 17	236 38	Direct.	−72 59·1	E.	+21	−35	−73 13		Table more steady, and steering very well.
			Def. N.	−71 56·0	E.	+21	−81	−72 56		
			Def. S.	−73 02·3	E.	+21	−35	−73 16		
			Mag. N.	−73 09·9	E.	+21	−35	−73 24		
			Mag. N.S.	−72 59·8	E.	+21	−35	−73 14	−73 08	Table more steady, and steering very well.
			Mag. S.	−72 54·8	E.	+21	−35	−73 13		
			Direct.	−73 01·8	E.	+21	−35	−73 16		
	−60 24	237 29	Direct.	−73 08·6	E. by N.	+37	−35	−73 06		
			Def. N.	−72 17·2	E. by N.	+37	−81	−73 01		
			Def. S.	−73 09·0	E. by N.	+37	−35	−73 07		
			Mag. N.	−73 09·7	E. by N.	+37	−35	−73 08		
			Mag. N.S.	−73 06·2	E. by N.	+37	−35	−73 04		
			Mag. S.	−73 07·2	E. by N.	+37	−35	−73 05		
			Direct.	−73 07·1	E. by N.	+37	−35	−73 05		
19.	−60 00	240 57	Direct.	−71 59·1	E.N.E.	+53	−35	−71 41	−71 24	Strong gale, heavy sea, steering badly.
20.	−59 18	245 29	Direct.	−72 17·9	N.E.	+78	−35	−71 35		
21.	−59 05	247 17	Direct.	−71 23·1	E. by N.	+37	−35	−71 21		Cross sea, slight motion.
			Def. N.	−70 26·9	E. by N.	+37	−81	−71 11		
			Def. S.	−71 26·8	E. by N.	+37	−35	−71 25		
			Mag. N.	−71 32·0	E. by N.	+37	−35	−71 30		
			Mag. N.S.	−71 20·1	E. by N.	+37	−35	−71 18		
			Mag. S.	−71 22·7	E. by N.	+37	−35	−71 21		
			Direct.	−71 20·9	E. by N.	+37	−35	−71 19		
	−59 00	248 49	Direct.	−71 53·4	N.E. ½ E.	+73	−35	−71 15		Head sea, table unsteady.

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections. Ship's attraction.	Corrections. Index.	True Inclination.		Remarks.
Mar. 22.	−58° 26′	251° 42′	Direct.	−71° 06′·1	E. by N.	+37′	−35′	−71° 04′	−70° 55′	Cross sea, unsteady.
			Def. N.	−70 01·3	E. by N.	+37	−81	−70 45		
			Def. S.	−70 45·2	E. by N.	+37	−35	−70 43		
			Mag. N.	−71 03·3	E. by N.	+37	−35	−71 01		
			Mag. N.S.	−70 44·0	E. by N.	+37	−35	−70 42		
			Mag. S.	−71 07·8	E. by N.	+37	−35	−71 06		
			Direct.	−71 02·9	E. by N.	+37	−35	−71 01		
23.	−58 33	254 45	Direct.	−70 24·7	E. ½ N.	+30	−35	−70 30	−70 16	Slight motion.
			Def. N.	−69 05·4	E. ½ N.	+30	−81	−69 56		
			Def. S.	−69 57·5	E. ½ N.	+30	−35	−70 03		
			Mag. N.	−70 02·7	E. ½ N.	+30	−35	−70 08		
			Mag. N.S.	−70 21·7	E. ½ N.	+30	−35	−70 27		
			Mag. S.	−70 10·1	E. ½ N.	+30	−35	−70 15		
			Direct.	−70 31·2	E. ½ N.	+30	−35	−70 36		
24.	−58 40	257 32	Direct.	−70 01·8	E. by N.	+37	−35	−70 00	−69 50	Slight motion.
			Def. N.	−69 09·1	E. by N.	+37	−81	−69 53		
			Def. S.	−69 43·7	E. by N.	+37	−35	−69 42		
			Mag. N.	−69 47·0	E. by N.	+37	−35	−69 45		
			Mag. N.S.	−69 37·4	E. by N.	+37	−35	−69 35		
			Mag. S.	−70 03·0	E. by N.	+37	−35	−70 01		
			Direct.	−70 01·8	E. by N.	+37	−35	−70 00		
			Direct.	−69 52·9	E.	+22	−35	−70 06		
	−58 49	258 13	Direct.	−69 51·1	E. by N.	+37	−35	−69 49		Table steady, very slight motion.
	−58 53	258 55	Direct.	−69 24·2	E. by N.	+37	−35	−69 32		
25.	−58 54	263 35	Direct.	−69 17·9	E.N.E.	+53	−35	−69 00	−68 00	Heavy sea, steering badly, a little motion.
26.	−58 59	267 50	Direct.	−68 19·8	E. by N. ½ N.	+44	−35	−68 11		
			Def. N.	−67 03·0	E. by N. ½ N.	+44	−81	−67 40		
			Def. S.	−68 05·4	E. by N. ½ N.	+44	−35	−67 56		
			Mag. N.	−67 44·2	E. by N. ½ N.	+44	−35	−67 35		
			Mag. N.S.	−67 52·6	E. by N. ½ N.	+44	−35	−67 44		
			Mag. S.	−67 52·5	E. by N. ½ N.	+44	−35	−67 44		
			Direct.	−68 15·6	E. by N. ½ N.	+44	−35	−68 07		
27.	−59 01	272 06	Direct.	−67 19·3	E.N.E.	+52	−35	−67 02	−66 53	A swell from the W.S.W., ship unsteady.
			Def. N.	−66 46·0	E.N.E.	+52	−81	−67 15		
			Def. S.	−67 09·6	E.N.E.	+52	−35	−66 53		
			Mag. N.	−66 53·0	E.N.E.	+52	−35	−66 36		
			Mag. N.S.	−66 59·0	E.N.E.	+52	−35	−66 42		
			Mag. S.	−67 05·8	E.N.E.	+52	−35	−66 49		
			Direct.	−67 17·8	E.N.E.	+52	−35	−67 01		
			Direct.	−67 04·7	E.N.E.	+52	−35	−66 48		
28.	−58 54	276 18	Direct.	−66 51·5	N.E. by E.	+64	−35	−66 23	−66 10	Swell from the W.S.W., ship unsteady.
			Def. N.	−65 48·2	N.E. by E.	+64	−81	−66 05		
			Def. S.	−66 53·4	N.E. by E.	+64	−35	−66 24		
			Mag. N.	−66 15·2	N.E. by E.	+64	−35	−65 46		
			Mag. N.S.	−66 18·7	N.E. by E.	+64	−35	−65 50		
			Mag. S.	−66 51·6	N.E. by E.	+64	−35	−66 23		
			Direct.	−66 51·8	N.E. by E.	+64	−35	−66 23		
29.	−58 25	279 44	Direct.	−65 05·3	N.E. by E.	+62	−35	−64 38	−64 44	Swell from S.W., slight motion.
			Direct.	−65 27·9	N.E. by E.	+62	−35	−65 01		
			Def. N.	−64 13·0	N.E. by E.	+62	−81	−64 32		
			Def. S.	−65 20·9	N.E. by E.	+62	−35	−64 54		
			Mag. N.	−65 03·0	N.E. by E.	+62	−35	−64 36		
			Mag. N.S.	−65 01·6	N.E. by E.	+62	−35	−64 35		
			Mag. S.	−65 08·8	N.E. by E.	+62	−35	−64 42		
			Direct.	−65 22·6	N.E. by E.	+62	−35	−64 56		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
Mar. 30.	−58 31	281 33	Direct.	−64 15·6	E.N.E.	+51	−35	−64 00	−63 48	Swell from S.W., slight motion.
			Direct.	−64 25·0	N.E. by E.	+62	−35	−63 58		
			Def. N.	−63 11·3	N.E. by E.	+62	−81	−63 30		
			Def. S.	−64 11·8	N.E. by E.	+62	−35	−63 45		
			Mag. N.	−64 05·6	N.E. by E.	+62	−35	−63 39		
			Mag. N.S.	−64 09·8	N.E. by E.	+62	−35	−63 43		
			Mag. S.	−64 27·0	N.E. by E.	+62	−35	−64 00		
			Direct.	−64 17·7	N.E. by E.	+62	−35	−63 51		
	−58 30	282 07	Direct.	−64 14·9	N.E. by E.	+62	−35	−63 48		
31.	−58 36	285 33	Direct.	−63 42·0	N.E.	+69	−35	−63 08	−63 00	Swell from S.W., slight motion.
			Def. N.	−62 50·6	N.E.	+69	−81	−63 03		
			Def. S.	−63 49·8	N.E.	+69	−35	−63 16		
			Mag. N.	−63 22·5	N.E.	+69	−35	−62 49		
			Mag. N.S.	−63 17·2	N.E.	+69	−35	−62 43		
			Mag. S.	−63 24·6	N.E.	+69	−35	−62 51		
			Direct.	−63 44·5	N.E.	+69	−35	−63 11		
April 1.	−57 21	289 36	Direct.	−62 26·9	N.E. by N.	+71	−35	−61 51	−61 36	Ship unsteady, steering very wildly.
			Def. N.	−61 16·8	N.E. by N.	+71	−81	−61 27		
			Def. S.	−62 04·7	N.E. by N.	+71	−35	−61 29		
			Mag. N.	−62 04·4	N.E. by N.	+71	−35	−61 28		
			Mag. N.S.	−62 12·7	N.E. by N.	+71	−35	−61 37		
			Mag. S.	−62 12·4	N.E. by N.	+71	−35	−61 36		
			Direct.	−62 17·0	N.E. by N.	+71	−35	−61 41		
2.	−57 26	291 32	Direct.	−58 55·8	S.E.	−33	−35	−60 04	−59 52	Heavy sea, ship unsteady.
			Def. N.	−57 57·1	S.E.	−33	−81	−59 51		
			Def. S.	−58 43·2	S.E.	−33	−35	−59 51		
			Mag. N.	−58 49·5	S.E.	−33	−35	−59 58		
			Mag. N.S.	−58 29·2	S.E.	−33	−35	−59 37		
			Mag. S.	−58 23·7	S.E.	−33	−35	−59 32		
			Direct.	−58 59·8	S.E.	−33	−35	−60 08		
	−57 25	292 02	Direct.	−58 22·4	S.S.E.	−62	−35	−59 59		
3.	−56 37	294 34	Direct.	−59 50·8	N.E.	+65	−35	−59 21	−59 02	Steering badly.
			Def. N.	−58 33·4	N.E.	+65	−81	−58 49		
			Def. S.	−59 43·5	N.E.	+65	−35	−59 13		
			Mag. N.	−59 19·3	N.E.	+65	−35	−58 49		
			Mag. N.S.	−59 26·3	N.E.	+65	−35	−58 56		
			Mag. S.	−59 21·8	N.E.	+65	−35	−58 52		
			Direct.	−59 45·5	N.E.	+65	−35	−59 16		
4.	−54 48	297 21	Direct.	−57 27·0	N. by E.	+66	−35	−56 56	−56 48	Heavy sea, strong breeze, steering badly.
			Def. N.	−56 43·5	N. by E.	+66	−81	−56 58		
			Def. S.	−57 23·2	N. by E.	+66	−35	−56 52		
			Mag. N.	−57 10·4	N. by E.	+66	−35	−56 39		
			Mag. N.S.	−57 13·4	N. by E.	+66	−35	−56 42		
			Mag. S.	−57 11·0	N. by E.	+66	−35	−56 40		
			Direct.	−57 19·0	N. by E.	+66	−35	−56 48		
5.	−52 40	299 52	Direct.	−54 40·0	N.N.E.	+58	−35	−54 17	−53 25	Ship steady.
			Def. N.	−53 51·3	N.N.E.	+58	−81	−54 14		
			Def. S.	−54 43·4	N.N.E.	+58	−35	−54 20		
			Mag. N.	−54 31·9	N.N.E.	+58	−35	−54 09		
			Mag. N.S.	−54 22·3	N.N.E.	+58	−35	−53 59		
			Mag. S.	−54 15·0	N.N.E.	+58	−35	−53 42		
			Direct.	−54 32·3	N.N.E.	+58	−35	−54 09		
	−52 35	300 33	Direct.	−53 51·0	N.N.E.	+58	−35	−53 28		
	−52 28	300 42	Direct.	−53 08·3	N. by E.	+57	−35	−52 46		
			Def. N.	−52 26·4	N. by E.	+57	−81	−52 50		
			Def. S.	−53 07·9	N. by E.	+57	−35	−52 46		

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.		Remarks.
						Ship's attraction.	Index.			
April 5.	−52° 28′	300° 42′	Mag. N.	−52° 50′·2	N. by E.	+57′	−35′	−52° 28′	−53° 25′	Ship steady.
			Mag. N.S.	−53 05·2	N. by E.	+57	−35	−52 43		
			Mag. S.	−53 00·8	N. by E.	+57	−35	−52 39		
			Direct.	−53 08·4	N. by E.	+57	−35	−52 46		
6.	−51 42	301 36	Direct.	−52 29·0	N.N.W. ½ W.	+54	−35	−52 10	−52 04	Strong breeze, slight motion.
			Def. N.	−51 20·0	N.N.W. ½ W.	+54	−81	−51 47		
			Def. S.	−52 35·9	N.N.W. ½ W.	+54	−35	−52 17		
			Mag. N.	−52 16·3	N.N.W. ½ W.	+54	−35	−51 57		
			Mag. N.S.	−52 20·7	N.N.W. ½ W.	+54	−35	−52 02		
			Mag. S.	−52 25·4	N.N.W. ½ W.	+54	−35	−52 06		
			Direct.	−52 24·5	N.N.W. ½ W.	+54	−35	−52 06		
9.	Port Louis, Falkland Islands.		Direct.	−51 32·8	W. ½ N.	+32	−35	−51 36		Single anchor.
			Def. N.	−50 51·4	W. ½ N.	+32	−81	−51 40		
			Def. S.	−52 09·8	W. ½ N.	+32	−35	−52 13		
11.	−51 32	301 53	Direct.	−51 36·7*	Observed on shore.		−35	−52 12	−52 15	
			Def. N.	−50 33·0			−81	−51 54		
			Def. S.	−52 08·6			−35	−52 44		
			Mag. N.	−51 33·1			−35	−52 08		
			Mag. N.S.	−51 34·1			−35	−52 09		
			Mag. S.	−51 42·3			−35	−52 17		
July 25.			Direct.	−51 34·4†			−35	−52 09		
			Def. N.	−51 03·7			−81	−52 25		
			Def. S.	−51 58·7			−35	−52 34		
			Mag. N.	−51 32·8			−35	−52 08		
			Mag. N.S.	−51 33·8			−35	−52 09		
			Mag. S.	−51 43·3			−35	−52 18		
			Direct.	−51 31·6‡			−35	−52 07		
			Def. N.	−51 00·8			−81	−52 22		
			Def. S.	−51 58·3			−35	−52 33		
			Mag. N.	−51 31·7			−35	−52 07		
			Mag. N.S.	−51 31·4			−35	−52 06		
			Mag. S.	−51 37·5			−35	−52 13		
			Direct.	−51 31·5			−35	−52 07		
			Direct.	−51 32·2§			−35	−52 07		
			Def. N.	−50 59·9			−81	−52 21		
			Def. S.	−51 58·3			−35	−52 33		
			Mag. N.	−51 31·9			−35	−52 07		
			Mag. N.S.	−51 32·3			−35	−52 07		
			Mag. S.	−51 44·3			−35	−52 19		

* Observed on shore; face west.
Direct. .. −52° 49′·6
Def. N. .. −53 05·3
Def. S. .. −52 48·3
Mag. N... −53 00·8
Mag. N.S. −53 09·7
Mag. S... −53 12·1

† Observed on shore; face west.
Direct. .. −52° 48′·7
Def. N. .. −53 42·2
Def. S. .. −52 48·4
Mag. N... −53 00·4
Mag. N.S. −53 06·2
Mag. S... −53 05·4

‡ Observed on shore; face west.
Direct. .. −52 39·5
Def. N. .. −53 30·8
Def. S. .. −52 57·9
Mag. N... −53 05·7
Mag. N.S. −53 01·8
Mag. S... −53 12·7
Direct. .. −52 38·6

§ Observed on shore; face west.
Direct. .. −52 41·5
Def. N. .. −53 46·8
Def. S. .. −52 56·4
Mag. N... −53 04·0
Mag. N.S. −53 02·4
Mag. S... −53 07·6

Observations of Inclination. (Continued.)

1842.	Lat.	Long.	Method employed.	Observed Inclination. Face east.	Direction of ship's head.	Corrections.		True Inclination.			Remarks.
						Ship's attraction.	Index.				
	° '	° '		° '		'	'	° '	° '	° '	
Aug. 15.	Berkeley Sound, Falkland Islands.		Direct.	−51 31·4	E. ½ S.	+22	−35	−51 44			
			Def. N.	−51 00·8	E. ½ S.	+22	−81	−52 00			
			Direct.	−51 45·5	E.	+28	−35	−51 52	−52 03	−51 56	
			Def. N.	−51 21·2	E.	+28	−81	−52 14			
			Direct.	−51 29·1	E.S.E.	+ 4	−35	−52 00	−52 11		
			Def. N.	−51 06·2	E.S.E.	+ 4	−81	−52 23			
			Direct.	−50 44·9	S.E.	−22	−35	−51 58	−52 02		
			Def. N.	−50 23·4	S.E.	−22	−81	−52 06			
			Direct.	−50 28·8	S.S.E.	−45	−35	−51 49	−51 54		
			Def. N.	−49 52·3	S.S.E.	−45	−81	−51 58			
			Direct.	−50 11·7	S.	−52	−35	−51 39	−51 46		
			Def. N.	−49 38·9	S.	−52	−81	−51 52			
			Direct.	−50 43·1	S.S.W.	−45	−35	−52 03	−52 06		
			Def. N.	−50 03·0	S.S.W.	−45	−81	−52 09			
			Direct.	−50 48·4	S.W.	−22	−35	−51 45	−51 54		
			Def. N.	−50 21·3	S.W.	−22	−81	−52 04			
			Direct.	−51 11·2	W.S.W.	+ 4	−35	−51 42	−51 42		
			Def. N.	−50 25·0	W.S.W.	+ 4	−81	−51 42			
			Direct.	−51 31·3	W.	+28	−35	−51 38	−51 45		
			Def. N.	−50 58·3	W.	+28	−81	−51 51			
			Direct.	−51 59·2	W.N.W.	+44	−35	−51 50	−51 55		
			Def. N.	−51 22·5	W.N.W.	+44	−81	−52 00			
			Direct.	−52 05·8	N.W.	+52	−35	−51 49	−51 53		
			Def. N.	−51 27·5	N.W.	+52	−81	−51 57			
			Direct.	−52 13·7	N.N.W.	+54	−35	−51 55	−51 48		
			Def. N.	−51 14·7	N.N.W.	+54	−81	−51 42			
			Direct.	−52 25·2	N.	+54	−35	−52 06	−51 52		
			Def. N.	−51 11·7	N.	+54	−81	−51 39			
			Direct.	−52 13·6	N.N.E.	+54	−35	−51 55	−51 58		
			Def. N.	−51 33·5	N.N.E.	+54	−81	−52 01			
			Direct.	−52 13·0	N.E.	+52	−35	−51 56	−51 56		
			Def. N.	−51 25·6	N.E.	+52	−81	−51 55			
			Direct.	−52 16·5	E.N.E.	+44	−35	−52 08	−52 07		
			Def. N.	−51 29·7	E.N.E.	+44	−81	−52 07			

Observations of the INTENSITY of the Magnetic FORCE made in Her Majesty's Ship Erebus, with Needle R. F. 5, between April 17, 1841, and August 23, 1842.

Observers Captain Sir JAMES CLARK ROSS and Lieutenant ALEXANDER SMITH, R.N.

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Apr. 19.	° ′ Magnetic Observatory, Hobarton.	° ′	Def. S.	56° 28′·6	64°	Observed on shore.	1·820	…….	….	1·820	Deflector employed R. F. 4.
			Def. N.	53 02·6	63						
	−42 52	147 24	wt. 6 grs.	42 55·7	61						
			wt. 5 grs.	34 23·5	60						
			wt. 4 grs.	26 47·7	60						
			wt. 3 grs.	19 37·2	60						
20.			wt. 2 grs.	13 02·8*	60						
June 29.	At anchor in the river Derwent.	To obtain corrections for the ship's attraction.	Def. S.	56 40·5	44	N.	1·809	+·024	….	1·832	1·830
			Def. S.	56 44·8	44	N.N.E.	1·806	+·022	….	1·828	
			Def. S.	56 34·3	45	N.E.	1·815	+·018	….	1·833	
			Def. S.	56 26·1	45	E.N.E.	1·820	+·013	….	1·833	
			Def. S.	56 24·4	47	E.	1·821	+·004	….	1·825	
			Def. S.	56 17·8	47	E.S.E.	1·825	—·006	….	1·819	
			Def. S.	55 52·9	48	S.E.	1·846	—·016	….	1·830	
			Def. S.	55 46·5	50	S.S.E.	1·851	—·023	….	1·828	
			Def. S.	55 42·7	48	S	1·854	—·026	….	1·822	
			Def. S.	55 48·7	48	S.S.W.	1·849	—·023	….	1·826	
			Def. S.	55 51·0	48	S.W.	1·847	—·016	….	1·831	
			Def. S.	56 10·3	48	W.S.W.	1·832	—·006	….	1·826	
			Def. S.	56 17·8	48	W.	1·825	+·004	….	1·829	
			Def. S.	56 15·3	48	W.N.W.	1·830	+·013	….	1·843	
			Def. S.	56 30·5	49	N.W.	1·817	+·018	….	1·835	
			Def. S.	56 29·0	48	N.N.W.	1·818	+·022	….	1·840	
			Def. S.	56 32·8	48	N.	1·815	+·024	….	1·839	
July 7.	Running out of Storm Bay.		Def. S.	55 37·6	49	S.E. ½ E.	1·858	—·014	1·842	1·842	
			Def. N.	52 16·3	47	S.E. ½ E.	1·854				
8.	−43 00	148 28	Def. S.	56 20·7	52	N.N.E.	1·823	+·022	1·837	1·837	A heavy head swell.
			Def. N.	53 12·2	52	N.N.E.	1·807				
9.	−42 13	149 25	Def. S.	57 03·3	56	N.N.W.	1·790	+·022	1·809	1·809	A head swell.
			Def. N.	53 37·1	56	N.N.W.	1·785				
10.	−40 54	149 13	Def. S.	57 07·3	54	N. by W.	1·786	+·024	1·804	1·804	
			Def. N.	53 51·6	60	N. by W.	1·773				
11.	−37 50	150 22	Def. N.	54 45·9	56	N. by W.	1·732	+·024	1·756	1·755	
12.	−37 21	151 33	Def. S.	58 08·0	61	N.E.	1·742	+·022	1·754		
			Def. N.	54 59·1	61	N.E.	1·722				
13.	−36 01	151 48	Def. N.	55 08·5	58	N.W. by N.	1·715	+·027	1·742	1·720	Much motion.
14.	−33 52	151 21	Def. S.	59 41·8	60	N.	1·676	+·031	1·708		Running along the land.
			Def. N.	55 55·6	60	N.	1·679				
15.	Garden Island, Sydney.		Def. S.	59 09·0	53	Observed on shore.	1·698	……	1·685	1·685	The results with the face west are included in the mean.
			Def. N.	55 35·9	52		1·694				
	−33 51	151 17	wt. 6 grs.	46 51·7	55		1·698				
			wt. 5 grs.	37 43·3	55		1·680				
			wt. 4 grs.	29 09·2	55		1·683				
			wt. 3 grs.	21 13·7	55		1·687				
			wt. 2 grs.	13 57·4	56		1·703				
			Def. S.	59 11·4†	52		1·696				
			Def. N.	55 38·1	52		1·692				

* Observed on shore; face west.

wt. 6 grs.	43° 07′·5	Ther. 58°
wt. 5 grs.	34 51·5	Ther. 58
wt. 4 grs.	27 02·7	Ther. 58
wt. 3 grs.	19 55·5	Ther. 60
wt. 2 grs.	13 14·5	Ther. 60

† Observed on shore; face west.

			Intensity.
wt. 6 grs.	47° 32′·4	Ther. 63°	1·688
wt. 5 grs.	37 38·9	Ther. 63	1·704
wt. 4 grs.	29 32·1	Ther. 64	1·680
wt. 3 grs.	21 51·4	Ther. 63	1·667
wt. 2 grs.	14 32·6	Ther. 64	1·662

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
	° ′			° ′	°						
July 15.	−33 51	151 17	Def. S.	59 11·5	64	W.	1·696	+·007	1·703	1·705	
Aug. 1.	At anchor.		Def. S.	58 21·4	61	S.	1·733	−·032	1·701		
			Def. S.	58 15·6	61	S.S.W.	1·737	−·028	1·709		
3.			Def. S.	59 29·0	63	N.E.	1·684	+·025	1·709		
5.	Running out of harbour.		Def. S.	59 09·4	63	E. by N.	1·698	+·011	1·709		
			Def. N.	55 46·8	63	E. by N.	1·686	+·011	1·697		
6.	−32 52	154 07	Def. S.	59 25·6	63	E. by N.	1·686	+·011	1·694	1·694	
			Def. N.	55 52·6	63	E. by N.	1·681				
7.	−33 51	157 18	Def. S.	60 05·3	60	E. by N.	1·660	+·011	1·667	1·667	Much motion.
			Def. N.	56 30·2	61	E. by N.	1·652				
8.	−33 27	160 43	Def. S.	60 18·0	63	E. by N.	1·651	+·011	1·655	1·655	
			Def. N.	56 53·1	64	E. by N.	1·638				
9.	−33 38	163 42	Def. S.	60 24·0	60	E.	1·647	+·007	1·642	1·642	
			Def. N.	57 14·4	61	E.	1·623				
10.	−33 41	166 23	Def. S.	61 22·7	63	N.E.	1·609	+·025	1·625	1·625	
			Def. N.	58 01·2	61	N.E.	1·591				
11.	−33 22	167 40	Def. S.	61 19·8	65	E. by N.	1·611	+·012	1·617	1·617	
			Def. N.	57 49·4	67	E. by N.	1·599				
12.	−32 58	169 20	Def. S.	61 40·0	56	E.N.E.	1·598	+·017	1·607	1·607	
			Def. N.	58 14·8	56	E.N.E.	1·582				
13.	−32 12	170 27	Def. S.	62 24·2	56	S.E. by E.	1·572	−·012	1·562	1·583	Much motion.
			Def. N.	58 24·4	55	S.E. by E.	1·576				
15.	−33 55	171 54	Def. S.	61 35·7	60	E. ½ S.	1·590	+·004	1·593		A head sea.
			Def. N.	53 05·6	60	E. ½ S.	1·588				
17.	−34 29	173 36	Def. S.	61 20·0	62	E.S.E.	1·611	−·006	1·594		Much motion.
			Def. N.	58 02·7	62	E.S.E.	1·590				
20.	At anchor.		Def. S.	61 57·7	66	N.W. ½ N.	1·587	+·025	1·612	1·607	
			Def. S.	60 42·9	63	S.	1·634	−·032	1·602		
23.	Bay of Islands, New Zealand.		Def. S.	61 41·1	58	Observed on shore.	1·599	......	1·594	1·594	The results with the face west are included in the mean.
			Def. N.	58 00·0	56		1·592				
	−35 16	174 00	wt. 6 grs.	50 38·1	58		1·604				
			wt. 5 grs.	40 10·5	58		1·594				
			wt. 4 grs.	30 55·0	59		1·597				
			wt. 3 grs.	22 47·5	59		1·578				
			wt. 2 grs.	14 59·3*	59		1·590				
Oct. 27.	−35 16	174 00	Def. S.	61 45·2	67		1·595				
			Def. N.	57 47·1	70		1·600				
			wt. 6 grs.	50 35·0	71		1·608				
			wt. 5 grs.	39 59·3	70		1·603				
			wt. 4 grs.	30 30·6	70		1·619				
			wt. 3 grs.	22 45·0	70		1·583				
			wt. 2 grs.	14 43·2	68		1·620				
			Def. S.	61 54·4	65		1·590				
			Def. N.	58 09·1†	65		1·586				
Nov. 23.	−35 15	174 39	Def. S.	61 00·9	63	E.S.E.	1·623	−·006	1·611	1·611	
			Def. N.	57 29·1	63	E.S.E.	1·611				
24.	−36 27	177 34	Def. S.	61 26·7	65	E.S.E.	1·607	−·006	1·612	1·612	
			Def. N.	57 12·7	64	E.S.E.	1·625				

* Observed on shore; face west.

	° ′	°	Intensity.
wt. 6 grs..	51 26·0	Ther. 61	1·591
wt. 5 grs..	40 52·0	Ther. 60	1·590
wt. 4 grs..	30 26·9	Ther. 59	1·633
wt. 3 grs..	23 17·9	Ther. 59	1·568
wt. 2 grs..	15 23·3	Ther. 60	1·571

† Observed on shore; face west.

	° ′	°	Intensity.
wt. 6 grs..	51 38·7	Ther. 65	1·588
wt. 5 grs..	40 51·0	Ther. 65	1·591
wt. 4 grs..	31 29·2	Ther. 65	1·586
wt. 3 grs..	23 17·2	Ther. 64	1·570
wt. 2 grs..	15 11·1	Ther. 64	1·593

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Tempera-ture.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Nov. 25.	−38° 17′	179° 31′	Def. S	60° 44′·4	62°	S.E. by S.	1·633	—·020	1·614	1·614	
			Def. N.	56 57·2	62	S.E. by S.	1·634				
26.	−39 01	182 12	Def. S.	62 02·7	59	E. by S.	1·585	—·000	1·605	1·615	Very much motion.
			Def. N.	57 12·9	57	E. by S.	1·625				
27.	−39 18	182 58	Def. S.	60 16·0	64	S.	1·652	—·028	1·625		
			Def. N.	56 29·9	62	S.	1·654				
28.	−40 47	183 03	Def. S.	59 58·5	62	S.E. by E.	1·664	—·010	1·659	1·659	
			Def. N.	56 03·4	65	S.E. by E.	1·674				
29.	−41 49	183 41	Def. S.	59 05·1	65	S. by E.	1·701	—·026	1·671	1·671	
			Def. N.	55 37·2	65	S. by E.	1·693				
30.	−43 32	183 03	Def. S.	58 24·9	60	S. ½ W.	1·732	—·027	1·701	1·701	
			Def. N.	54 54·9	59	S. ½ W.	1·724				
Dec. 1.	−45 40	183 20	Def. S.	58 32·2	63	S.E. by E.	1·725	—·010	1·715	1·730	A head sea.
			Def. N.	54 58·7	63	S.E. by E.	1·722				
2.	−47 19	184 40	Def. S.	57 40·9	57	S.E. by E. ½ E.	1·762	—·008	1·745		A heavy swell.
			Def. N.	54 30·5	57	S.E. by E. ½ E.	1·744				
3.	−48 43	186 30	Def. S.	57 41·3	51	S.E. by E.	1·762	—·009	1·752	1·753	
			Def. N.	54 10·1	51	S.E. by E.	1·760				
			wt. 2 grs.	13 28·0	51	E.S.E.	1·765	—·005	1·760		
4.	—49 20	187 41	Def. S.	57 45·8	55	E. by S.	1·757	·000	1·752		
			Def. N.	54 13·1	55	E. by S.	1·758				
			wt. 3 grs.	20 30·2	53	E. by S.	1·745				
			wt. 4 grs.	27 58·0	53	E. by S.	1·750				
5.	−49 27	189 13	Def. S.	57 32·7	55	E. by S.	1·770	·000	1·759	1·759	
			Def. N.	54 16·0	55	E. by S.	1·757				
			wt. 3 grs.	20 18·0	56	E. by S.	1·762				
			wt. 4 grs.	27 32·0	56	E. by S.	1·775				
			wt. 5 grs.	36 30·1	56	E. by S.	1·729				
6.	−50 00	191 00	Def. S.	57 30·2	51	E. by S.	1·771	·000	1·763	1·766	
			Def. N.	54 13·5	51	E. by S.	1·758				
			wt. 3 grs.	20 22·2	51	E. by S.	1·754				
			wt. 4 grs.	27 16·5	51	E. by S.	1·789				
			wt. 5 grs.	36 07·2	51	E. by S.	1·742				
7.	−50 48	192 20	Def. S.	57 07·9	51	S.E. by E.	1·787	—·009	1·774		
			Def. N.	53 45·7	51	S.E. by E.	1·779				
8.	−51 34	194 29	Def. S.	57 06·4	52	E. by S.	1·789	·000	1·792	1·792	
			Def. N.	53 15·7	50	E. by S.	1·804				
			wt. 3 grs.	20 09·1	48	E. by S.	1·771				
			wt. 4 grs.	26 59·7	48	E. by S.	1·804				
			wt. 5 grs.	34 58·0	47	E. by S.	1·791				Weight 5, unsteady.
9.	−52 21	197 53	Def. S.	56 44·5	45	E. by S.	1·805	·000	1·801	1·808	
			Def. N.	53 25·1	44	E. by S.	1·797				
10.	−53 01	202 11	Def. S.	56 21·2	48	E. ½ N.	1·824	+·006	1·815		Much motion.
			Def. N.	53 27·0	47	E. ½ N.	1·794				
11.	−52 48	203 50	Def. N.	53 13·3	45	E.	1·807	+·003	1·809		A head swell.
			Def. S.	56 45·0	46	E.	1·805				
			wt. 3 grs.	19 57·7	46	E.	1·797				
12.	−53 01	205 08	Def. S.	56 37·4	45	E.S.E.	1·811	—·004	1·810	1·810	
			Def. N.	52 57·3	44	E.S.E.	1·818				
			wt. 3 grs.	19 46·7	45	E.S.E.	1·802				
			wt. 4 grs.	26 41·5	45	E.S.E.	1·823				
			wt. 5 grs.	34 25·7	45	E.S.E.	1·815				
13.	−54 55	209 30	Def. S.	56 08·7	52	S.E. by E. ½ E.	1·833	—·007	1·831	1·831	
			Def. N.	52 26·0	51	S.E. by E. ½ E.	1·846				
	−55 08	210 04	Def. S.	56 02·2	49	S.E. by E. ½ E.	1·839				
			Def. N.	52 30·7	48	S.E. by E. ½ E.	1·842				
	−55 20	210 28	Def. S.	56 10·0	45	S.E. by E. ½ E.	1·832				
			Def. N.	52 38·2	44	S.E. by E. ½ E.	1·836				

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Dec. 14.	−56° 20′	211° 52′	Def. S.	55° 38′·9	51°	s.e. by s.	1·857	−·016	1·836	1·836	
			Def. N.	52 01·3	51	s.e. by s.	1·868				
			wt. 3 grs.	19 37·5	53	s.e. by s.	1·818				
			wt. 4 grs.	26 08·7	52	s.e. by s.	1·860				
			wt. 5 grs.	33 36·0	52	s.e. by s.	1·856				
			wt. 6 grs.	42 36·0	52	s.e. by s.	1·830				
	−56 55	211 38	Def. S.	55 33·2	43	s.e. by s.	1·863				
			Def. N.	51 59·7	43	s.e. by s.	1·868				
15.	−56 55	212 34	Def. S.	55 28·0	41	s.s.e.	1·865	−·017	1·843	1·850	
			Def. N.	52 17·0	40	s.s.e.	1·856				
	−57 21	212 46	Def. S.	55 29·8	42	e.s.e.	1·864	−·004	1·858		
			Def. N.	52 10·0	41	e.s.e.	1·860				
16.	−58 29	213 11	Def. S.	55 19·7	42	s.s.e.	1·872	−·017	1·873	1·873	
			Def. N.	51 52·9	42	s.s.e.	1·874				
	−58 52	213 22	Def. S.	54 57·6	41	s.s.e.	1·889				
			Def. N.	52 04·5	41	s.s.e.	1·865				
			wt. 3 grs.	18 32·2	38	s.s.e.	1·916				
			wt. 4 grs.	25 25·0	38	s.s.e.	1·906				
			wt. 5 grs.	32 31·2	38	s.s.e.	1·907				
17.	−61 03	213 57	Def. S.	54 19·2	39	s.s.e.	1·923	−·017	1·903	1·908	
			Def. N.	51 06·0	36	s.s.e.	1·918				
	−61 37	213 57	Def. S.	54 02·4	34	s. by e.	1·939	−·018	1·913		
			Def. N.	51 01·2	32	s. by e.	1·922				
18.	−62 40	212 53	Def. S.	53 43·6	34	s.	1·953	−·019	1·922	1·922	
			Def. N.	50 50·0	32	s.	1·931				
19.	−63 23	210 02	Def. S.	53 39·8	39	s.s.w.	1·958	−·017	1·939	1·939	
			Def. N.	50 26·0	38	s.e.w.	1·954				
			Def. S.	54 33·8	42	Observed on ice.	1·910	……	1·923	1·923	
			Def. N.	50 44·7	45		1·936				
20.	−63 47	208 26	Def. S.	53 58·3	35	s. by w.	1·941	−·018	1·924	1·930	
			Def. N.	50 36·8	34	s. by w.	1·944				
			wt. 3 grs.	18 22·9	35	s.w. by s.	1·938	−·012	1·934		
			wt. 4 grs.	25 05·6	34	s.w. by s.	1·935				
			wt. 5 grs.	32 11·8	34	s.w. by s.	1·926				
			wt. 6 grs.	40 03·5	34	s.w. by s.	1·926				
21.	−64 38	206 53	Def. S.	54 00·1	32	s.	1·940	−·016	1·926	1·933	
			Def. N.	50 35·6	31	s.	1·944				
	−64 53	206 30	Def. S.	53 34·4	44	s. by w.	1·963	−·015	1·934		
			Def. N.	50 23·4	39	s. by w.	1·956				
			wt. 8 grs.	18 15·6	33	s. ½ e.	1·942	−·016	1·934		
			wt. 4 grs.	24 39·8	33	s.	1·959				
			wt. 5 grs.	31 35·1	33	s. by e.	1·955	−·015	1·939		
			wt. 6 grs.	39 11·3	33	s. by e.	1·954				
22.	−65 36	205 32	Def. S.	53 33·1	37	s.	1·964	−·016	1·954	1·955	
			Def. N.	50 00·6	36	s.	1·977				
23.	−65 59	204 16	Def. S.	53 51·4	44	e.n.e.	1·948	+·006	1·954		
			Def. S.	53 38·5	37	s. by w.	1·959	−·013	1·964		
			Def. N.	49 48·2	36	s. by w.	1·996				
	−65 59	204 14	Def. S.	53 31·5	39	s.	1·965	−·014	1·956		
			Def. N.	50 05·6	35	s.	1·973				
24.	−65 58	203 51	Def. S.	53 21·6	43	s.w. by s.	1·976	−·010	1·957		Fast to a piece of ice.
			Def. N.	50 19·8	43	s.w. by s.	1·959				
25.	−66 00	203 46	Def. S.	53 56·5	34	e.	1·943	+·002	1·953		
			Def. N.	50 19·4	35	e.	1·959				
26.	−66 11	203 36	Def. S.	53 43·3	30	s.e. by e.	1·955	−·005	1·954		
			Def. N.	50 16·2	30	s.e. by e.	1·963				
			Def. S.	54 01·9	30	n.w.	1·939	+·010	1·953		
29	−66 24	203 51	Def. S.	53 51·7	42	n.e.	1·947				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Jan. 1.	−66° 32′	203° 32′	Def. S.	53° 23′·8	44°	S.S.E.	1·972	−·012	1·966	1·965	Fast to a piece of ice, the Terror distant 25 fathoms. (This result is not employed in the Map.)
			Def. N.	49 53·5	44	S.S.E.	1·984				
3.	−66 35	203 25	Def. S.	53 48·9	39	N. by W. ½ W.	1·950	+·012	1·965		
			Def. N.	50 21·7	37	N. by W. ½ W.	1·957				
6.	−66 06	204 24	Def. S.	53 28·7	41	S.	1·967	−·014	1·955	1·954	Sailing through loose ice.
			Def. N.	50 01·7	38	S.	1·976				
			wt. 3 grs.	18 01·8	37	S.	1·964				
			wt. 4 grs.	24 44·9	37	S.	1·953				
			wt. 5 grs.	30 55·2	36	S.	1·994				
			wt. 6 grs.	38 50·1	36	S.	1·970				
7.	−66 13	204 25	Def. S.	53 38·9	33	S.	1·958				
			Def. N.	50 07·5	32	S.	1·971				
8.	−66 12	204 33	Def. S.	53 50·4	35	N.W.	1·948	+·010	1·958		
			Def. N.	50 32·2	35	N.W.	1·948				
			Def. S.	53 47·9	34	S.S.E.	1·951	−·012	1·939		
10.	−65 59	204 12	Def. S.	53 49·5	36	S.W. by W.	1·949	−·005	1·947	1·957	
			Def. N.	50 25·4	30	S.W. by W.	1·955				
			Def. N.	50 15·4	30	E.	1·964	+·002	1·966		
			wt. 3 grs.	18 09·9	30	E.	1·951				
			wt. 4 grs.	24 37·5	30	E.	1·960				
			wt. 5 grs.	31 12·1	30	E.	1·975				
			wt. 6 grs.	38 45·9	30	E.	1·971				
12.	−65 54	203 32	Def. S.	53 33·4	32	S.W.	1 963	−·008	1·955		
13.	−66 12	203 05	Def. S.	53 41·3	40	S.S.E.	1·957	−·012	1·949		
			Def. N.	50 13·9	36	S.S.E.	1·965				
			Def. S.	54 11·3	30	N.N.E.	1·932	+·012	1·946		
			Def. N.	50 46·1	30	N.N.E.	1·935				
16.	−65 49	202 02	Def. S.	54 03·1	45	Observed on ice.	1·938	.....	1·943	1·943	
			Def. N.	50 35·0	45		1·945				
			wt. 2 grs.	12 13·0	50		1·940				
			wt. 3 grs.	18 32·4	54		1·992				
			wt. 4 grs.	24 49·3	54		1·952				
			wt. 5 grs.	32 02·4	54		1·936				
			wt. 6 grs.	39 31·4	55		1·946				
21.	−66 49	202 40	Def. S.	53 19·1	37	S. by E.	1·975	−·013	1·961	1·960	
			Def. N.	50 05·6	36	S. by E.	1·973				
28.	−67 33	204 01	Def. N.	50 24·8	34	N.	1·955	+·012	1·967		
29.	−67 32	203 59	Def. S.	53 28·8	31	S.S.W.	1·967	−·012	1·957		
			Def. N.	50 08·2	30	S.S.W.	1·971				
30.	−67 18	203 39	Def. S.	53 35·7	38	S.W. ½ S.	1·961	−·009	1·959		
			Def. N.	50 06·7	36	S.W. ½ S.	1·972				
			wt. 3 grs.	18 00·0	34	S.W. ½ S.	1·970				
31.	−67 21	202 15	Def. S.	53 36·7	35	S.W.	1·961	−·008	1·951	1·951	
			Def. N.	50 08·2	32	S.W.	1·971				
			wt. 3 grs.	18 19·6	33	S.W.	1·936				
			wt. 4 grs.	24 44·5	33	S.W.	1·953				
			wt. 5 grs.	31 23·7	35	S.W.	1·965				
			wt. 6 grs.	38 52·0	35	S.W.	1·968				
Feb. 2.	−68 07	200 15	Def. S.	53 23·2	31	S.S.E. ½ E.	1·972	−·011	1·971	1·975	Much motion.
			Def. N.	49 46·2	31	S.S.E. ½ E.	1·992				
3.	−68 21	200 03	Def. S.	52 54·7	32	S.E. by S.	1·997	−·010	1·981		
			Def. N.	49 52·6	31	S.E. by S.	1·985				
4.	−68 42	199 44	Def. S.	52 57·1	33	S. ½ E.	1·995	−·014	1·974		
			Def. N.	49 51·4	30	S. ½ E.	1·987				
			wt. 3 grs.	18 05·7	30	S. ½ E.	1·961				
			wt. 4 grs.	23 55·7	29	S. ½ E.	2·014				
			wt. 5 grs.	31 02·0	30	S. ½ E.	1·985				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Feb. 5.	−68° 59′	195° 51	Def. S.	53° 13′·7	33°	s.w. by s.	1·981	−·004	1·972	1·985	A great deal of motion.
			Def. N.	50 07·0	32	s.w. by s.	1·972				
6.	−69 48	192 25	Def. S.	52 42·1	36	s. by w.	2·010	−·008	1·991		
			Def. N.	49 49·0	34	s. by w.	1·989				
7.	−70 05	191 10	Def. S.	52 46·1	29	s.w.	2·006	−·005	2·008		
			Def. N.	49 18·3	29	s.w.	2·020				
			Def. S.	53 21·7	33	s.s.w.	1·973	−·007	1·972		
			Def. N.	49 52·7	30	s.s.w.	1·985				
8.	−70 18	186 01	Def. S.	53 05·0	37	s.	1·989	−·009	1·977	1·980	
			Def. N.	49 46·8	33	s.	1·991				
			wt. 3 grs.	18 21·8	31	s.	1·931				
			wt. 4 grs.	24 06·1	31	s.	2·001				
			wt. 5 grs.	30 40·6	31	s.	2·006				
			wt. 6 grs.	38 05·3	30	s.	2·001				
9.	−70 39	185 31	Def. S.	52 56·5	32	s.e. by s.	1·996	−·006	1·987		
			Def. N.	49 47·4	29	s.e. by s.	1·991				
10.	−70 06	181 50	Def. S.	53 09·0	33	w. by s.	1·985	·000	1·981	1·983	A head swell.
			Def. N.	50 00·2	31	w. by s.	1·978				
11.	−70 10	181 34	Def. N.	50 03·7	33	s.w.	1·975	−·005	1·972		Much motion.
12.	−71 00	180 44	Def. S.	52 49·2	33	s.e. by s.	2·003	−·005	1·992		A heavy cross sea.
			Def. N.	49 45·7	32	s.e. by s.	1·992				
13.	−72 46	181 46	Def. S.	52 55·6	34	s.e. by s.	1·997	−·003	1·973	1·973	
			Def. N.	49 45·5	32	s.e. by s.	1·992				
			wt. 3 grs.	18 17·2	31	s.e. by s.	1·940				
			wt. 4 grs.	24 23·0	31	s.e. by s.	1·975				
16.	−74 56	173 36	Def. S.	53 16·1	26	s.s.e.	1·979	−·003	1·998	2·008	Very unsteady.
			Def. N.	49 49·5	26	s.s.e.	1·988				
			wt. 3 grs.	17 23·0	26	s.s.e.	2·036				
	−75 10	173 08	Def. S.	52 39·5	36	e.	2 017	+·001	2·009		
			Def. N.	49 45·9	30	e.	1·992				
			wt. 3 grs.	17 20·9	27	e.	2·039				
			wt. 4 grs.	23 58·7	27	e.	2·009				
			wt. 5 grs.	30 59·1	28	e.	1·987				
			wt. 6 grs.	38 02·3	27	e.	2·002				
17.	−76 00	175 15	Def. S.	52 38·3	33	e.n.e.	2·014	+·002	2·010	2·005	
			Def. N.	49 33·5	31	e.n.e.	2·004				
18.	−76 58	181 03	Def. S.	53 00·7	28	e.n.e.	1·993	+·002	2·003		
			Def. N.	49 29·3	27	e.n.e.	2·009				
19.	−76 42	184 09	Def. S.	53 06·2	25	n. by e.	1·988	+·004	2·001		Ship pitching.
			Def. N.	49 31·3	25	n. by e.	2·007				
22.	−76 42	194 48	Def. S.	52 59·0	30	n. by e.	1·993	+ 004	1·999	1·993	A swell from the south.
			Def. N.	49 41·0	28	n. by e.	1·997				
	−77 05	194 38	Def. S.	53 10·6	36	e. by s.	1·984	+·001	1·991		
			Def. N.	49 57·5	33	e. by s.	1·981				
			wt. 3 grs.	18 06·5	29	e. by s.	1·960				
			wt. 4 grs.	23 18·7	29	e. by s.	2·063				
			wt. 5 grs.	31 25·7	29	e. by s.	1·961				
			wt. 6 grs.	38 04·1	29	e. by s.	2·000				
25.	−74 50	193 45	Def. S.	53 14·8	30	w.	1·980	+·001	1·983	1·983	
			Def. N.	49 54·3	29	w.	1·984				
26.	−72 46	189 59	Def. S.	53 30·5	37	n.w. by w.	1·966	+·002	1·972	1·974	
			Def. N.	50 04·5	31	n.w. by w.	1·974				
27.	−72 01	187 35	Def. S.	53 32·7	26	w. by s.	1·964	+·000	1·976		
			Def. N.	49 49·1	25	w. by s.	1·989				
28.	−71 08	184 59	Def. S.	53 27·6	31	w.	1·968	+·001	1·975	1·993	
			Def. N.	49 57·0	26	w.	1·981				
			wt. 3 grs.	17 39·5	25	w.s.w.	2·004	·000	2·012		
			wt. 4 grs.	23 52·0	25	w.s.w.	2·020				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Mar. 1.	−69° 52′	180° 00′	Def. S.	53° 10′·7	33°	W. by N.	1·983	+·003	1·980	1·978	A swell from the northward.
			Def. N.	50 06·0	31	W. by N.	1·972				
	−69 44	179 53	Def. S.	53 28·1	32	N. by E.	1·968	+·007	1·976		
			Def. N.	50 09·7	29	N. by E.	1·969				
2.	−68 04	183 25	Def. S.	54 05·0	33	N.N.E.	1·936	+·008	1·962	1·965	
			Def. N.	50 06·7	32	N.N.E.	1·972				
			Def. S.	53 46·5	34	N.E. by N.	1·951	+·008	1·969		
			Def. N.	50 09·3	32	N.E. by N.	1·970				
3.	−67 32	185 09	Def. S.	53 24·5	30	E.N.E.	1·971	+·005	1·976	1·964	
			Def. N.	50 08·8	31	E.N.E.	1·971				
5.	−67 16	188 10	Def. N.	50 40·2	35	N. by E.	1·941	+·010	1·952		
6.	−65 25	191 48	Def. N.	50 38·3	34	N. by E.	1·943				A very heavy swell from westward, observations very uncertain.
7.	−63 30	194 52	Def. S.	54 11·9	40	N. by E.	1·930	+·010	1·936	1·925	
			Def. N.	50 54·2	35	N. by E.	1·927				
			wt. 3 grs.	18 26·2	33	N. by E.	1·925				
			wt. 4 grs.	25 10·3	33	N. by E.	1·922				
8.	−62 16	196 10	Def. S.	54 52·7	35	N. by E.	1·893	+·010	1·903		
			Def. N.	51 32·2	35	N. by E.	1·893				
9.	−61 14	198 38	Def. S.	54 38·4	43	N.E. by N.	1·907	+·013	1·914	1·909	
			Def. N.	51 23·2	35	N.E. by N.	1·902				
			wt. 3 grs.	19 06·9	33	N.E. by N.	1·859				
			wt. 4 grs.	25 25·5	35	N.E. by N.	1 905				
			wt. 5 grs.	32 00·5	34	N.E. by N.	1·933				
	−60 50	200 11	Def. S.	55 00·4	38	E.N.E.	1·888	+·007	1·895		
			Def. N.	51 37·2	35	E.N.E.	1·888				
10.	−60 18	204 11	Def. S.	55 52·5	35	E. by N.	1·844	+·005	1·869	1·869	Cross sea, ship very unsteady.
			Def. N.	51 56·5	34	E. by N.	1·871				
12.	−60 13	211 34	Def. S.	55 28·0	35	E. by N.	1·862				A heavy swell, very unsteady.
			Def. N.	51 47·5	35	E. by N.	1·879				
14.	−59 24	218 58	Def. S.	55 52·2	37	N.E. by E.	1·846	+·011	1·863	1·863	A heavy swell, very unsteady.
			Def. N.	52 20·0	37	N.E. by E.	1·851				
	−59 16	219 30	Def. S.	55 37·4	37	N.E. by E.	1·859				
			Def. N.	52 18·2	37	N.E. by E.	1·853				
15.	−58 04	222 04	Def. S.	55 54·2	37	E.N.E.	1·844	+·009	1·864		
			Def. N.	52 16·4	37	E.N.E.	1·844				
			wt. 3 grs.	18 57·0	38	E.N.E.	1·876				
16.	−59 04	228 57	Def. S.	55 28·7	39	E.	1·864	+·002	1·869	1·875	
			Def. N.	51 57·5	39	E.	1·870				
17.	−59 39	232 48	Def. S.	55 21·3	39	E. ½ S.	1·872	+·001	1·878		A great deal of motion.
			Def. N.	51 57·5	39	E. ½ S.	1·870				
	−59 45	233 53	Def. S	55 12·0	40	E. ½ S.	1·879				
			Def. N.	51 41·2	38	E. ½ S.	1·885				Very unsteady.
18.	−60 16	236 11	Def. S.	54 40·7	36	E. by S.	1·901	·000	1·897	1·894	
			Def. N.	51 33·2	35	E. by S.	1·893				
			Def. S.	55 00·2	37	E.	1·888	+·003	1·892		
	−60 21	237 02	Def. S.	55 12·5	39	E.	1·879				Ship rolling, very unsteady.
			Def. N.	51 25·6	39	E.	1·899				
	−60 20	237 50	Def. S.	55 33·4	39	E. by N.	1·862	+·009	1·890	1·892	
			Def. N.	51 25·5	39	E. by N.	1·899				
	−60 19	238 00	Def. S.	55 10·2	40	E. by N. ½ N.	1·880	+·010	1·894		
			Def. N.	51 37·9	39	E. by N. ½ N.	1·887				
19.	−60 01	241 38	Def. S.	55 58·9	39	E.N.E.	1·841	+·011	1·851	1·846	Much motion.
			Def. N.	52 25·0	37	E.N.E.	1·846				
			Def. S.	56 13·5	42	E.N.E.	1·829				
			Def. N.	52 30·0	40	E.N.E.	1·842				
21.	−59 15	248 12	Def. S.	56 07·0	39	E. by N.	1·836	+·009	1·839		
			Def. N.	52 51·5	38	E. by N.	1·824				
	−58 58	249 24	Def. S.	56 11·2	39	N.E. by E.	1·831	+·015	1·841		
			Def. N.	52 56·0	38	N.E. by E.	1·820				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Mar. 22.	−58° 29′	252° 22′	Def. S.	56° 30′·5	38°	E. ½ S.	1·816	+·002	1·816	1·807	A head sea.
			Def. N.	53 05·6	38	E. ½ S.	1·812				
23.	−58 35	255 10	Def. S.	56 36·0	34	E. ½ N.	1·812	+·006	1·804		
			Def. N.	53 13·2	33	E. ½ N.	1·807				
25.	−58 44	257 49	Def. S.	56 35·8	36	E. ½ N.	1·812				
			Def. N.	53 16·7	35	E. ½ N.	1·803				
			wt. 3 grs.	20 17·0	34	E. ½ N.	1·756				
26.	−59 02	268 30	Def. S.	57 19·2	47	E. by N. ½ N.	1·778	+·012	1·783	1·733	Ship unsteady.
			Def. N.	54 05·2	45	E. by N. ½ N.	1·763				
27.	−59 02	272 02	Def. S.	58 55·6	37	E.N.E.	1·707	+·014	1·722		
			Def. N.	55 17·7	35	E.N.E.	1·708				
28.	−58 50	277 12	Def. S.	59 34·0	40	N.E. by E.	1·681	+·018	1·694		
			Def. N.	56 07·7	39	N.E. by E.	1·671				
29.	−58 23	280 03	Def. S.	60 45·2	44	N.E. ½ E.	1·633	+·019	1·651	1·639	
			Def. N.	57 03·0	45	N.E. ½ E.	1·631				
30.	−58 29	282 04	Def. S.	60 30·3	40	N.E. by E. ½ E.	1·643	+·016	1·651		
			Def. N.	57 08·2	40	N.E. by E. ½ E.	1·627				
31.	−58 29	286 04	Def. N.	58 34·2	45	N.E. by N.	1·570	+·024	1·594		A heavy swell from the southward.
Apr. 1.	−57 22	289 50	Def. S.	63 22·7	47	N.E. by N.	1·539	+·025	1·554	1·532	
			Def. N.	60 00·8	47	N.E. by N.	1·519				
2.	−57 10	292 11	Def. S.	63 27·2	44	S.E.	1·535	−·017	1·510		
			Def. N.	59 57·5	44	S.E.	1·520				
3.	−56 40	294 46	Def. S.	65 38·2	46	N.E.	1·465	+·023	1·466	1·466	
			Def. N.	61 36·2	45	N.E.	1·469				
4.	−54 50	298 10	Def. N.	64 10·7	44	N.E.	1·395				
5.	−52 54	300 57	Def. S.	70 13·4	48	N.N.E.	1·342	+·025	1·355	1·355	
			Def. N.	66 55·7	45	N.N.E.	1·327				
			wt. 3 grs.	27 57·7	43	N.N.E.	1·300				
			wt. 4 grs.	37 33·2	44	N.N.E.	1·340				
			wt. 5 grs.	49 40·7	44	N.N.E.	1·343				
11.	Port Louis, Falkland Islands. −51 32	301 53	Def. S.	70 51·3	47	Observed on shore.	1·328	……	1·322	1·322	The results with the "face west" are included in the mean.
			Def. N.	67 08·1	47		1·322				
			wt. 2 grs.	18 31·1	45		1·291				
			wt. 3 grs.	27 42·7	45		1·311				
			wt. 4 grs.	37 58·5	43		1·331				
			wt. 5 grs.	48 55·9	43		1·361				
			wt. 6 grs.	66 49·8*	43		1·345				
Aug. 19.			wt. 2 grs.	17 57·1	37		1·330				
			wt. 3 grs.	27 43·3	37		1·310				
			wt. 4 grs.	37 40·4	37		1·339				
			wt. 5 grs.	49 31·4	38		1·347				
			wt. 6 grs.	67 23·4*	38		1·339				
			Def. S.	71 32·4	34		1·311				
			Def. N.	67 12·6	35		1·320				

			Temp.	Intensity.
* Observed on shore; face west.	wt. 2 grs.	18° 50′·4	42	1·287
	wt. 3 grs.	28 30·0	42	1·296
	wt. 4 grs.	38 51·0	41	1·315
	wt. 5 grs.	51 27·9	41	1·326
	wt. 6 grs.	68 40·3	41	1·332
	wt. 2 grs.	18 32·9	39	1·306
	wt. 3 grs.	28 26·6	40	1·299
	wt. 4 grs.	39 05·3	40	1·309
	wt. 5 grs.	51 19·2	40	1·329
	wt. 6 grs.	69 35·7	40	1·324

Observations of the INTENSITY of the Magnetic FORCE made in Her Majesty's Ship Terror, with Needle F. C. B., between April 16, 1841, and August 15, 1842.

Observers Captain FRANCIS RAWDON CROZIER, and Mr. THOMAS MOORE, Mate, R.N.

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Apr. 17.	Hobarton Magnetic Observatory. −42° 52′	147° 24′	Def. S.	33° 20′·4	60°	Observed on shore.	1·820	……..	1·820	A spare needle marked C. was used as a deflector, and the observations with it are those registered as "Deflector S." and "Deflector N." The deflecting magnets belonging to the apparatus were also employed, N alone, and N. and S. conjointly. The observations with these are distinguished as "Mag. N." and "Mag. N.S." The temperatures are taken from the register in the Erebus.
			Mag. N.S.	39 59·2	60					
			Mag. N.	30 04·0	60					
			Def. S.	21 03·1	60					
19.			wt. 1 gr.*	12 11·9	60					
			wt. 1½ gr.	18 29·4	60					
			wt. 2 grs.	25 13·7	60					
			wt. 2½ grs.	31 43·0	60					
			wt. 3 grs.	39 02·3	60					
			wt. 3½ grs.	46 51·3	60					
20.			Def. N.	36 00·6	60					
			Def. S.	33 25·6	60					
			Mag. N.S.	40 11·6	60					
			Mag. N.	30 24·1	60					
June 22.	At anchor in the river Derwent.	To obtain corrections for the ship's attraction.	Def. N.	35 58·5	48	W.	1·821			
			Def. N.	35 49·1	48	W.S.W.	1·831			
			Def. N.	35 34·5	48	S.W.	1·844			
			Def. N.	35 09·6	48	S.S.W.	1·868			
			Def. N.	35 09·3	48	S.	1·868			
			Def. N.	34 58·0	48	S.S.E.	1·879			
			Def. N.	35 00·0	48	S.E.	1·877			
			Def. N.	34 59·9	48	E.S.E.	1·877			
			Def. N.	35 06·4	48	E.	1·871			
			Def. N.	35 13·9	48	E.N.E.	1·863			
			Def. N.	35 18·4	48	N.E.	1·859			
			Def. N.	35 21·6	48	N.N.E.	1·857			
			Def. N.	35 23·0	48	N.	1·855			
			Def. N.	35 23·7	48	N.N.W.	1·854			
			Def. N.	36 04·1	48	N.W.	1·816			
			Def. N.	35 21·4	48	W.N.W.	1·857			
July 7.	Storm Bay.		Def. N.	34 57·0	48	S.E. ¾ E.	1·880	−·012	1·860	Very steady.
			Def. S.	32 40·0	48	S.E. ¾ E.	1·864			
8.	−43 03	148 20	Def. N.	35 23·6	52	W. ½ N.	1·854	+·006	1·849	Very steady.
			Def. S.	33 11·5	52	W. ½ N.	1·832			
9.	−42 24	149 30	Def. N.	36 03·7	56	N.N.W.	1·816	+·022	1·822	Very steady.
			Def. S.	33 57·6	56	N.N.W.	1·785			
10.	−40 51	149 28	Def. N.	36 33·8	56	N. by W.	1·787	+·025	1·814	Very steady.
			Def. S.	33 51·3	56	N. by W.	1·792			
11.	−38 17	150 22	Def. N.	36 46·1	56	N. by E.	1·775	+·027	1·785	Very steady.
			Def. S.	34 43·3	56	N. by E.	1·741			
12.	−37 28	151 30	Def. N.	37 09·4	61	N.E. ½ N.	1·752	+·023	1·758	Slight motion.
			Def. S.	35 06·4	61	N.E. ½ N.	1·718			
13.	−36 21	151 39	Def. N.	37 15·1	58	N.N.W. ½ W.	1·747	+·026	1·738	Steering very steady.
14.	−34 06	151 19	Def. N.	38 06 6	60	N.	1·697	+·031		Heavy cross sea, unsteady.
			Def. S.	35 42·8	60	N.	1·681			A slight motion.
19.	Garden Island, Port Jackson.		Def. N.	38 05·9	60	Observed on shore.	1·697			Steering steady.
	−33 51	151 17	Def. S.	35 15·7	60		1·708			

* Observed on shore; face west.

wt. 1 gr.	11° 42′·0	Intensity 1·820
wt. 1½ gr.	17 52·6	
wt. 2 grs.	24 15·6	
wt. 2½ grs.	31 00·7	
wt. 3 grs.	38 42·3	
wt. 3½ grs.	46 06·3	

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
July 19.	Garden Island, Port Jackson.		Mag. N.S.	41° 45′·3	60°	Observed on shore.	1·705	......	1·699	Including the results with the "face west."
			Mag. N.	31 47·2	60		1·696			
			Mag. S.	22 06·6	60					
			wt. 1 gr.*	13 08·8	60		1·691			
			wt. 1½ gr.	20 02·0	60		1·685			
			wt. 2 grs.	27 00·7	60		1·708			
			wt. 2½ grs.	34 25·2	60		1·692			
			wt. 3 grs.	42 06·9	60		1·709			
			wt. 3½ grs.	51 13·5	60		1·703			
Aug. 5.	Running out of harbour.		Def. N.	37 45·1	63	E. by N. ½ N.	1·718	+·014	1·719	A head swell.
			Def. S.	35 36·2	63	E. by N. ½ N.	1·688			
			Def. N.	37 36·2	63	E. by N. ½ N.	1·726			
			Def. S.	35 34·5	63	E. by N. ½ N.	1·690			
6.	−34 01	153 17	Def. N.	38 06·3	63	E. by N.	1·698	+·011	1·703	
			Def. S.	36 11·3	63	E. by N.	1·654			
	−33 54	153 54	Def. N.	37 32·3	63	E. by N.	1·731			
			Def. S.	35 38·8	63	E. by N.	1·685			
7.	−33 56	156 38	Def. N.	38 16·4	61	E. by N.	1·688	+·011	1·679	Steering wildly, much motion.
			Def. S.	36 19·2	61	E. by N.	1·647			
8.	−33 31	160 20	Def. N.	38 36·0	63	E. by N.	1·669	+·011	1·671	A good deal of motion, steering tolerably.
			Def. S.	36 13·2	63	E. by N.	1·652			
9.	−33 42	163 34	Def. N.	38 58·3	61	E.	1·648	+·007	1·658	Much motion, steering badly.
			Def. S.	36 16·0	61	E.	1·650			
		164 05	Def. N.	38 46·2	61	E.	1·659			
			Def. S.	36 18·3	61	E.	1·648			
10.	−33 47	166 39	Def. N.	38 57·3	62	E. by N. ½ N.	1·648	+·014	1·627	Motion violent, steering wild.
			Def. S.	37 01·9	62	E. by N. ½ N.	1·604			
	−33 42	166 36	Def. N.	39 30·7	62	E.	1·616	+·007		A long swell, motion quick, steering well.
			Def. S.	36 57·2	62	E.	1·609			
			Mag. N.	32 50·1	62	E.	1·609			
			Mag. S.	23 37·2	62	E.				
11.	−33 34	167 37	Def. N.	40 07·5	66	N.E. by E.	1·579	+·020	1·600	Light wind, heavy swell, with quick motion.
			Def. S.	37 58·5	66	N.E. by E.	1·549			
			Mag. N.	33 03·0	66	N.E. by E.	1·592			
			Mag. S.	23 12·0	66	N.E. by E.				
			Mag. N.S.	43 13·0	66	N.E. by E.	1·590			
			Def. N.	39 46·4	66	E.	1·600	+·007		
12.	−32 58	169 20	Def. N.	40 10·5	56	E.N.E.	1·576	+·018	1·607	Wind fresh, motion quick, steering badly.
			Def. S.	37 19·5	56	E.N.E.	1·586			
			Mag. N.	32 56·3	56	E.N.E.	1·601			
			Mag. S.	24 07·8	56	E.N.E.				
			Mag. N.S.	43 17·9	56	N.E.	1·585	+·026		
13.	−32 12	170 27	Def. N.	39 31·5	55	S.E. by E.	1·615	−·012	1·589	A head sea, steering steadily.
			Def. S.	37 17·6	55	S.E. by E.	1·588			
14.	−32 11	171 20	Def. N.	38 55·5	55	S.E. by E.	1·650			Strong wind, heavy sea, motion quick, ship steering well.
			Def. S.	36 58·7	55	S.E. by E.	1·607			
			Mag. N.	33 30·8	55	S.E. by E.	1·554			
			Mag. N.S.	43 09·9	55	S.E. by E.	1·595			
			Mag. S.	23 34·3	55	S.E. by E.				

* Observed on shore; face west.			Intensity.
	wt. 1 gr.	12° 44′·1	1·674
	wt. 1½ gr.	19 03·3	1·712
	wt. 2 grs.	26 01·2	1·705
	wt. 2½ grs.	33 17·7	1·709
	wt. 3 grs.	41 35·2	1·715
	wt. 3½ grs.	51 02·1	1·687

Observations of the Magnetic Force. (Continued.)

	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
15.	−33° 55′	171° 59′	Def. N.	39° 35′·3	60°	E. by s.	1·611	·000	1·601	A head sea, table very unsteady.
			Def. N.	39 46·2	60	E. ½ N.	1·600	+·010		
	−33 58	172 06	Def. N.	39 09·4	60	E.S.E.	1·637	−·006		
			Def. S.	37 06·3	60	E.S.E.	1·600			
			Mag. N.	33 20·9	60	E.S.E.	1·566			
			Mag. N.S.	43 00·2	60	E.S.E.	1·609			
			Mag. S.	23 21·3	60	E.S.E.				
16.	−34 15	172 50	Def. N	39 43 1	61	N.W. by N.	1·603	+·029	1·597	A head sea, wind strong, steering well.
			Def. S.	37 44·5	61	N.W. by N.	1·562			
			Mag. N.	33 10·3	61	N.W. by N.	1·583			
			Mag. N.S.	43 25·9	61	N.W. by N.	1·573			
			Mag. S.	23 38·1	61	N.W. by N.				
			Mag. N.S.	43 40·5	61	E. by s. ½ s.	1·554	−·004		Heavy swell, steering well.
17.	−34 24	173 43	Def. N.	38 52·7	62	E. by s. ½ s.	1·653	−·004	1·619	Strong wind, good deal of motion.
			Def. S.	36 57·2	62	E. by s. ½ s.	1·609			
			Mag. N.	32 46·0	62	E. by s. ½ s.	1·616			
			Mag. N.S.	42 50·3	62	E. by s. ½ s.	1·622			
			Mag. S.	23 06·2	62	E. by s. ½ s.				
18.	?	?	Def. N.	38 54·8	64	s.w.	1·631	−·018		A heavy sea, steeri wild,
21.	Bay of Islands, New Zealand.		Def. N.	39 40·9	59	Observed on shore.	1·606			
			Def. S.	36 59·8	59		1·606			
			Mag. N.	32 50·2	59		1·610			
	−35 16	174 00	Mag, N.S.	43 01·9	59		1·606			
			Mag. S,	23 37·6	59					
			wt. 1 gr.*	14 03·2	59		1·584			
			wt. 1½ gr.	21 17·9	59		1·601			
			wt. 2 grs.	28 22·1	59		1·633			
			wt. 2½ grs.	36 50·7	59		1·596			
			wt. 3 grs.	44 58·3	59		1·622			
			wt. 3½ grs.	55 09·9	59		1·618	……	1·608	At the M servat result west ' in th
Oct. 29.			Def. N.	39 32·8	64		1·613			
			Def. S.	36 57·6	64		1·608			
			Mag. N.	32 51·5	64		1·608			
			Mag. N.S.	42 54·9	64		1·616			
			Mag. S.	23 37·6	64					
			wt. 1 gr.†	13 51·7	64		1·606			
			wt. 1½ gr.	20 53·0	64		1·620			
			wt. 2 grs.	28 22·4	64		1·633			
			wt. 2½ grs.	37 05·6	64		1·587			
			wt. 3 grs.	45 02·2	64		1·621			
			wt. 3½ grs.	55 19·1	64		1·616			
Nov. 23.	Running out of Bay of Islands, off Arch Point.		Def. N.	39 41·1		E. by s.	1·605	+·004	1·610	
			Def. S.	36 59·1		E. by s.	1·607			
24.	−36 20	177 27	Def. N.	39 11·0		E.S.E.	1·635	+·001	1·616	
			Def. S.	36 24·1		E.S.E.	1·642			
			Mag. N.	33 07·5		E.S.E.	1·586			
			Mag. N.S.	43 07·0		E.S.E.	1·599			
			Mag. S.	23 09·3		E.S.E.				

* Observed on shore; face west.

		Intensity.
wt. 1 gr.	13° 24′·3	1·592
wt. 1½ gr.	20 30·5	1·595
wt. 2 grs.	27 46·9	1·605
wt. 2½ grs.	35 43·0	1·607
wt. 3 grs.	44 38·7	1·619
wt. 3½ grs.	55 23·7	1·594

† Observed on shore; face west.

wt. 1 gr.
wt. 1½ gr.
wt. 2 grs.
wt. 2½ g
wt. 3 gr
wt. 3½

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
	° ′	° ′		° ′	°					
Nov. 25.	−38 00	179 34	Def. N.	39 01·2		S.E. by S.	1·645	−·018	1·634	A head sea, table not very steady.
			Def. S.	36 28·2		S.E. by S.	1·638			
			Mag. N.	32 25·3		S.E. by S.	1·645			
			Mag. N.S.	42 31·1		S.E. by S.	1·647			
			Mag. S.	23 06·8		S.E. by S.				
	−38 27	179 59	Def. N.	38 52·4		S.E. by E. ½ E.	1·654	−·002		A sea from the S.W., ship unsteady.
			Def. S.	36 29·4		S.E. by E. ½ E.	1·637			
			Mag. N.	32 22·4		S.E. by E. ½ E.	1·643			
			Mag. N.S.	42 30·0		S.E. by E. ½ E.	1·648			
			Mag. S.	22 37·9		S.E. by E. ½ E.				
26.	−38 48	182 05	Def. N.	39 12·6		E.S.E.	1·633	+·001	1·640	Ship very steady, steering well.
			Def. S.	36 36·7		E.S.E.	1·629			
			Def. N.	39 06·7		S.E.	1·639			
			Def. S.	36 32·6		S.E.	1·633	−·013		
			Mag. N.	32 23·2		S.E.	1·648			
			Mag. N.S.	42 20·3		S.E.	1·662			
			Mag. S.	22 23·4		S.E.				
	−39 02	182 05	Def. N.	38 54·4		E.S.E.	1·653			Head sea, much motion.
			Def. S.	36 15·2		E.S.E.	1·650	+·001		
			Mag. N.	32 30·5		E.S.E.	1·638			
			Mag. N.S.	42 19·3		E.S.E.	1·663			
			Mag. S.	22 25·8		E.S.E.				
27.	−39 14	182 54	Def. N.	38 52·7	63	S.E. by E.	1·653	−·006	1·652	A swell from the S.E., ship steady.
			Def. S.	36 27·2	63	S.E. by E.	1·639			
			Mag. N.	32 35·6	63	S.E. by E.	1·631			
			Mag. N.S.	42 34·9	63	S.E. by E.	1·641			
			Mag. S.	22 45·9	63	S.E. by E.				
	−39 31	183 00	Def. N.	38 39·5	63	S. by E.	1·666	−·024		Steering well, ship steady.
			Def. S.	35 59·9	63	S. by E.	1·665			
			Mag. N.	32 11·1	63	S. by E.	1·663			
			Mag. N.S.	42 13·5	63	S. by E.	1·666			
			Mag. S.	22 43·5	63	S. by E.				
28.	−40 35	183 00	Def. N.	38 32·3	64	E.S.E.	1·673	·000		Very steady.
			Def. S.	35 52·8	64	E.S.E.	1·672			
			Mag. N.	32 12·2	64	E.S.E.	1·662			
			Mag. N.S.	41 59·7	64	E.S.E.	1·686			
			Mag. S.	22 29·6	64	E.S.E.				
	−40 50	183 11	Def. N.	38 27·2	64	S.S.E. ½ E.	1·678	−·019		
			Def. S.	35 35·2	64	S.S.E. ½ E.	1·689			
			Mag. N.	32 02·5	64	S.S.E. ½ E.	1·675			
			Mag. N.S.	41 46·1	64	S.S.E. ½ E.	1·706			
			Mag. S.	22 29·8	64	S.S.E. ½ E.				
29.	−41 34	183 40	Def. N.	38 16·1	65	S. by E.	1·689	−·023	1·666	Very steady.
			Def. S.	35 28·7	65	S. by E.	1·695			
			Mag. N.	31 55·0	65	S. by E.	1·686			
			Mag. N.S.	41 32·6	65	S. by E.	1·720			
			Mag. S.	22 14·3	65	S. by E.				
			wt. 1 gr.	13 24·0	65	S. by E.	1·660			
			wt. 1½ gr.	20 07·1	65	S. by E.	1·678			
			wt. 2 grs.	26 39·6	65	S. by E.	1·729			
			wt. 2½ grs.	35 07·5	65	S. by E.	1·663			
			wt. 3 grs.	42 38·1	65	S. by E.	1·692			
			wt. 3½ grs.	52 14·9	65	S. by E.	1·680			
	−42 40	183 46	Def. N.	38 04·4	65	S.	1·700	−·025	1·682	Very steady.
			Def. S.	35 21·7	65	S.	1·702			
			Mag. N.	31 38·8	65	S.	1·708			
			Mag. N.S.	41 34·5	65	S.	1·717			
			Mag. S.	22 01·6	65	S.				

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Nov. 30.	−43° 33′	183° 10′	Def. N.	37° 47′·0	59°	s. ½ w.	1·717	—·024	1·707	Very steady.
			Def. S.	35 15·2	59	s. ½ w.	1·709			
			Mag. N.	31 33·3	59	s. ½ w.	1·716			
			Mag. N.S.	41 28·2	59	s. ½ w.	1·727			
			Mag. S.	21 58·1	59	s. ½ w.				
	−44 15	183 02	Def. N.	37 29·0	59	s. by w.	1·734	—·023		A cross swell, motion slight.
			Def. S.	34 31·6	59	s. by w.	1·752			
			Mag. N.	31 18·9	59	s. by w.	1·737			
			Mag. N.S.	41 10·5	59	s. by w.	1·747			
			Mag. S.	21 59·4	59	s. by w.				
Dec. 1.	−45 30	183 12	Def. N.	37 08·5	63	s.e. by e.	1·753	—·007	1·733	Ship pitching considerably, steeri very steadily.
			Def. S.	34 49·3	63	s.e. by e.	1·735			
			Mag. N.	31 29·9	63	s.e. by e.	1·721			
			Mag. N.S.	41 29·2	63	s.e. by e.	1·725			
			Mag. S.	21 42·2	63	s.e. by e.				
	−45 48	183 25	Def. N.	37 11·4	63	s.e. ½ e.	1·750	—·010		A head sea, table unsteady, ship steering well.
			Def. S.	34 52·1	63	s.e. ½ e.	1·732			
			Mag. N.	31 06·0	63	s.e. ½ e.	1·753			
			Mag. N.S.	40 59·4	63	s.e. ½ e.	1·762			
			Mag. S.	21 43·6	63	s.e. ½ e.				
2.	−47 13	184 30	Def. N.	37 11·8	56	s.e. by e. ½ e.	1·750	—·002	1·753	Head sea, ship pitc ing, steering steadily.
			Def. S.	34 31·8	56	s.e. by e. ½ e.	1·752			
			Mag. N.	31 15·8	56	s.e. by e. ½ e.	1·741			
			Mag. N.S.	41 12·7	56	s.e. by e. ½ e.	1·744			
			Mag. S.	21 07·2	56	s.e. by e. ½ e.				
	−47 39	184 55	Def. N.	36 53·8	56	s.e. by e.	1·767	—·007		
			Def. S.	34 24·0	56	s.e. by e.	1·760			
			Mag. N.	30 55·2	56	s.e. by e.	1·768			
			Mag. N.S.	40 53·0	56	s.e. by e.	1·772			
			Mag. S.	21 09·8	56	s.e. by e.				
3.	−48 18	185 54	Def. N.	36 55·9	51	s.e. by e.	1·765	—·007	1·772	Very steady.
			Def. S.	34 06·7	51	s.e. by e.	1·776			
			Mag. N.	30 44·1	51	s.e. by e.	1·782			
			Mag. N.S.	40 52·8	51	s.e. by e.	1·772			
			Mag. S.	21 15·0	51	s.e. by e.				
			wt. 1 gr.	12 01·0	51	s.e. by e.	1·844			
			wt. 1½ gr.	18 51·1	51	s.e. by e.	1·784			
			wt. 2 grs.	25 50·7	51	s.e. by e.	1·777			
			wt. 2½ grs.	32 51·6	51	s.e. by e.	1·760			
			wt. 3 grs.	40 23·1	51	s.e. by e.	1·766			
			wt. 3½ grs.	48 41·0	51	s.e. by e.	1·765			
	−49 05	186 54	Def. N.	36 51·6	51	s.e. by e. ½ e.	1·769	—·005	1·772	Very s
			Def. S.	34 06·3	51	s.e. by e. ½ e.	1·777			
			Mag. N.	30 46·1	51	s.e. by e. ½ e.	1·780			
			Mag. N.S.	40 45·8	51	s.e. by e. ½ e.	1·781			
			Mag. S.	21 11·2	51	s.e. by e. ½ e.				
			wt. 1 gr.	12 23·7	51	s.e. by e. ½ e.	1·790			
			wt. 1½ gr.	18 37·4	51	s.e. by e. ½ e.	1·804			
			wt. 2 grs.	25 50·1	51	s.e. by e. ½ e.	1·778			
			wt. 2½ grs.	32 30·9	51	s.e. by e. ½ e.	1·777			
			wt. 3 grs.	40 32·8	51	s.e. by e. ½ e.	1·760			
			wt. 3½ grs.	48 59·5	51	s.e. by e. ½ e.	1·757			
4.	−49 24	187 23	Def. N.	36 41·8	54	e.	1·779	+·004		
			Def. N.	36 44·7	54	e. by s.	1·776	—·000	1·772	s
			Def. S.	34 22·0	54	e. by s.	1·762			
			Mag. N.	30 48·7	54	e. by s.	1·776			
			Mag. N.S.	40 56·3	54	e. by s.	1·768			

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Dec. 4.	−49° 24′	187° 23′	Mag. S.	21° 25′·6	54	E. by S.		·000	1·772	Swell from the northward. Steady.
			wt. 1 gr.	12 24·3	54	E. by S.	1·789			
			wt. 1½ gr.	18 55·0	54	E. by S.	1·778			
			wt. 2 grs.	25 46·4	54	E. by S.	1·782			
			wt. 2½ grs.	32 36·7	54	E. by S.	1·774			
			wt. 3 grs.	40 48·6	54	E. by S.	1·753			
			wt. 3½ grs.	48 56·7	54	E. by S.	1·759			
5.	−49 23	188 54	Def. N.	36 18·3	55	E. by S.	1·803			
			Def. S.	34 29·5	55	E. by S.	1·754	·000	1·775	Very steady.
			Mag. N.	30 46·1	55	E. by S.	1·780			
			Mag. N.S.	40 54·9	55	E. by S.	1·770			
			Mag. S.	21 34·1	55	E. by S.				
			wt. 1 gr.	12 35·7	55	E. by S.	1·762			
			wt. 1½ gr.	18 20·9	55	E. by S.	1·831			
			wt. 2 grs.	25 35·5	55	E. by S.	1·794			
			wt. 2½ grs.	32 51·2	55	E. by S.	1·762			
			wt. 3 grs.	40 31·3	55	E. by S.	1·762			
			wt. 3½ grs.	48 46·6	55	E. by S.	1·764			
	−49 38	189 44	Def. N.	36 34·4	55	E. by S.	1·787			
			Def. S.	34 28·8	55	E. by S.	1·755			
			Mag. N.	30 54·8	55	E. by S.	1·766			
			Mag. N.S.	41 01·8	55	E. by S.	1·759			
			Mag. S.	21 46·8	55	E. by S.				
6.	−49 50	190 46	Def. N.	36 37·1	51	E. by S.	1·784	·000	1·766	Very steady.
			Def. S.	34 02·5	51	E. by S.	1·781			
			Mag. N.	30 49·4	51	E. by S.	1·775			
			Mag. N.S.	41 04·2	51	E. by S.	1·756			
			Mag. S.	21 41·3	51	E. by S.				
			wt. 1 gr.	12 38·8	51	E. by S.	1·753			
			wt. 1½ gr.	18 49·6	51	E. by S.	1·785			
			wt. 2 grs.	25 40·4	51	E. by S.	1·788			
			wt. 2½ grs.	33 28·2	51	E. by S.	1·725			
			wt. 3 grs.	40 37·3	51	E. by S.	1·758			
			wt. 3½ grs.	49 09·5	51	E. by S.	1·753			
	−50 08	191 39	Def. N.	36 40·0	51	E. by S.	1·781	·000	1·771	Ship steady.
			Def. S.	34 16·4	51	E. by S.	1·768			
			Mag. N.	30 51·3	51	E. by S.	1·774			
			Mag. N.S.	41 02·2	51	E. by S.	1·759			
			Mag. S.	21 42·4	51	E. by S.				
			wt. 1 gr.	12 35·7	51	E. by S.	1·761			
			wt. 1½ gr.	18 50·0	51	E. by S.	1·785			
7.	−50 32	191 52	Def. N.	35 51·7	51	S.E. by E.	1·828			
			Def. S.	33 46·7	51	S.E. by E.	1·796	−·007	1·777	Ship steady.
			Mag. N.	30 48·4	51	S.E. by E.	1·778			
			Mag. N.S.	40 47·4	51	S.E. by E.	1·780			
			Mag. S.	21 27·7	51	S.E. by E.				
	−50 45	192 19	Def. N.	36 01·8	51	S.E. ½ E.	1·818	−·008		
			Def. S.	34 06·7	51	S.E. ½ E.	1·776			
			Mag. N.	30 40·7	51	S.E. ½ E.	1·785			
			Mag. N.S.	40 45·7	51	S.E. ½ E.	1·782			
			Mag. S.	21 32·3	51	S.E. ½ E.				
			wt. 1 gr.	12 43·0	51	S.E. ½ E.	1·743			
			wt. 1½ gr.	18 56·2	51	S.E. ½ E.	1·776			
			wt. 2 grs.	25 58·6	51	S.E. ½ E.	1·769			
			wt. 2½ grs.	32 37·7	51	S.E. ½ E.	1·772			
			wt. 3 grs.	40 35·6	51	S.E. ½ E.	1·759			
			wt. 3½ grs.	48 00·8	51	S.E. ½ E.	1·784			

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Tempera-ture.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Dec. 8.	−51° 37′	194° 00′	Def. N.	35° 49′·9	49°	E. by S.	1·830			
			Def. S.	33 50·1	49	E. by S.	1·793			
			Mag. N.	30 42·2	49	E. by S.	1·784			
			Mag. N.S.	40 31·4	49	E. by S.	1·796			
			Mag. S.	21 29·1	49	E. by S.				
			wt. 1 gr.	12 35·5	49	E. by S.	1·760	·000	1·794	Ship steady.
			wt. 1½ gr.	18 34·6	49	E. by S.	1·806			
			wt. 2 grs.	25 16·9	49	E. by S.	1·813			
			wt. 2½ grs.	32 08·9	49	E. by S.	1·794			
			wt. 3 grs.	40 00·3	49	E. by S.	1·780			
			wt. 3½ grs.	48 01·8	49	E. by S.	1·782			
	−52 00	195 00	Def. N.	36 01·2	49	E. by S.	1·819			
			Def. S.	33 59·6	49	E. by S.	1·783			
			Mag. N.	30 36·5	49	E. by S.	1·792			Strong breeze, table steady, steering wildly.
			Mag. N.S.	40 38·6	49	E. by S.	1·786			
			Mag. S.	20 59·5	49	E. by S.				
9.	−52 14	197 49	Def. N.	35 53·6	45	E. by S.	1·826	·000	1·799	
			Def. S.	33 44·6	45	E. by S.	1·798			
			Mag. N.	30 21·9	45	E. by S.	1·812			
			Mag. N.S.	40 47·0	45	E. by S.	1·781			Ship unsteady, steering wild.
			Mag. S.	20 38·5	45	E. by S.				
10.	−53 01	202 16	Mag. N.S.	40 36·2	45	E. by S.	1·791			
11.	−52 51	203 56	Def. N.	36 14·8	46	E. ½ N.	1·805			
			Def. S.	33 54·6	46	E. ½ N.	1·788			
			Mag. N.	30 26·7	46	E. ½ N.	1·806			
			Mag. N.S.	40 30·9	46	E. ½ N.	1·798			
			Mag. S.	21 26·5	46	E. ½ N.				
			wt. 1 gr.	11 50·3	46	E. ½ N.	1·871	+·008		Violent motion, steering well, head sea, table pretty steady.
			wt. 1½ gr.	17 43·9	46	E. ½ N.	1·891			
			wt. 2 grs.	24 29·7	46	E. ½ N.	1·867			
			wt. 2½ grs.	31 19·3	46	E. ½ N.	1·837			
			wt. 3 grs.	39 46·3	46	E. ½ N.	1·788			
			wt. 3½ grs.	47 43·1	46	E. ½ N.	1·791		1·820	
12.	−52 53	205 07	Def. N.	36 41·3	45	E.S.E.	1·780			
			Def. S.	33 40·8	45	E.S.E.	1·802			
			Mag. N.	30 30·2	45	E.S.E.	1·801			
			Mag. N.S.	40 20·2	45	E.S.E.	1·813			
			Mag. S.	21 23·0	45	E.S.E.				
			wt. 1 gr.	12 30·8	45	E.S.E.	1·771	−·003		Head swell, little motion, steering well.
			wt. 1½ gr.	18 07·9	45	E.S.E.	1·851			
			wt. 2 grs.	24 38·0	45	E.S.E.	1·857			
			wt. 2½ grs.	31 44·7	45	E.S.E.	1·815			
			wt. 3 grs.	39 30·1	45	E.S.E.	1·798			
			wt. 3½ grs.	48 07·9	45	E.S.E.	1·779			
	−53 31	206 14	Def. N.	36 09·5	45	E.S.E.	1·811			
			Def. S.	33 22·8	45	E.S.E.	1·820			
			Mag. N.	30 11·3	45	E.S.E.	1·828			
			Mag. N.S.	39 57·5	45	E.S.E.	1·841			
			Mag. S.	21 07·1	45	E.S.E.				
			wt. 1 gr.	12 08·9	45	E.S.E.	1·823	−·003	1·834	A slight motion, steering very well.
			wt. 1½ gr.	18 00·7	45	E.S.E.	1·863			
			wt. 2 grs.	24 39·1	45	E.S.E.	1·856			
			wt. 2½ grs.	31 15·2	45	E.S.E.	1·840			
			wt. 3 grs.	38 03·7	45	E.S.E.	1·855			
			wt. 3½ grs.	47 41·3	45	E.S.E.	1·834			

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Dec. 13.	−54° 19′	208° 24′	Def. N.	36° 02′·0	51°	E.S.E.	1·818	—·003		Table steady, steering badly.
			Def. S.	33 17·8	51	E.S.E.	1·825			
			Mag. N.	30 23·2	51	E.S.E.	1·811			
			Mag. N.S.	40 28·8	51	E.S.E.	1·801			
			Mag. S.	20 27·6	51	E.S.E.			1·814	
	−54 53	209 24	Def. N.	36 03·0	51	E.S.E.	1·817			
			Def. S.	33 14·6	51	E.S.E.	1·828			
			Mag. N.	30 10·5	51	E.S.E.	1·829			
			Mag. N.S.	39 59·5	51	E.S.E.	1·837			
			Mag. S.	20 52·6	51	E.S.E.				
	−54 48	209 25	Def. N.	36 18·6	51	E.S.E.	1·802			Heavy sea, steering badly.
	−55 04	209 58	Def. N.	36 11·8	48	S.E. by S.	1·808	—·015		
			Def. S.	32 54·1	48	S.E. by S.	1·849			Ship much more steady, steering better.
			Mag. N.	30 18·1	48	S.E. by S.	1·818			
			Mag. N.S.	40 03·9	48	S.E. by S.	1·831			
			Mag. S.	20 54·4	48	S.E. by S.				
14.	−56 14	211 43	Def. N.	35 54·6	52	S.E. by S.	1·825	—·015	1·836	Table steady, steering well.
			Def. S.	32 37·1	52	S.E. by S.	1·867			
			Mag. N.	29 56·6	52	S.E. by S.	1·849			
			Mag. N.S.	39 36·9	52	S.E. by S.	1·867			
			Mag. S.	20 21·6	52	S.E. by S.				
			Def. N.	35 55·5	52	S.E. by S.	1·824			
			Def. S.	32 43·8	52	S.E. by S.	1·860			
			Mag. N.	29 59·3	52	S.E. by S.	1·845			
			Mag. N.S.	39 31·8	52	S.E. by S.	1·874			
			Mag. S.	20 24·4	52	S.E. by S.				
	−56 30	211 50	Def. N.	35 36·6	52	S.E. by S.	1·841	—·015	1·841	Very steady.
			Def. S.	32 43·4	52	S.E. by S.	1·861			
			Mag. N.	29 59·9	52	S.E. by S.	1·844			
			Mag. N.S.	40 01·6	52	S.E. by S.	1·834			
			Mag. S.	20 33·4	52	S.E. by S.				
			wt. 1 gr.	11 46·1	52	S.E. by S.	1·884			
			wt. 1½ gr.	18 10·6	52	S.E. by S.	1·848			
			wt. 2 grs.	24 02·0	52	S.E. by S.	1·902			
			wt. 2½ grs.	31 08·6	52	S.E. by S.	1·848			
			wt. 3 grs.	38 07·8	52	S.E. by S.	1·855			
			wt. 3½ grs.	46 00·9	52	S.E. by S.	1·846			
15.	−56 53	212 06	Def. N.	35 33·1	41	S.E. by S.	1·845	—·015	1·843	Very steady.
			Def. S.	32 47·5	41	S.E. by S.	1·855			
			Mag. N.	29 57·1	41	S.E. by S.	1·848			
			Mag. N.S.	40 06·1	41	S.E. by S.	1·828			
			Mag. S.	20 33·2	41	S.E. by S.				
	−57 16	212 17	Def. N.	35 28·4	41	S.E. by S.	1·850			
			Def. S.	32 21·9	41	S.E. by S.	1·882			
			Mag. N.	29 25·4	41	S.E. by S.	1·895			
			Mag. N.S.	39 39·1	41	S.E. by S.	1·865			
			Mag. S.	20 14·7	41	S.E. by S.				
16.	−57 44	212 59	Def. N.	35 13·8	42	S.S.E.	1·863	—·019	1·863	Very steady.
			Def. S.	32 22·3	42	S.S.E.	1·882			
			Mag. N.	29 51·2	42	S.S.E.	1·857			
			Mag. N.S.	39 30·9	42	S.S.E.	1·876			
			Mag. S.	20 15·2	42	S.S.E.				
			wt. 1 gr.	11 45·4	42	S.S.E.	1·882			
			wt. 1½ gr.	18 00·2	42	S.S.E.	1·860			
			wt. 2 grs.	23 38·6	42	S.S.E.	1·929			
			wt. 2½ grs.	30 04·6	42	S.S.E.	1·904			

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Dec. 16.	−58° 28′	213° 08′	Def. N.	34° 42′·2	42°	S.S.E.	1·895	—·017	1·878	Very steady.
			Def. S.	32 09·3	42	S.S.E.	1·896			
			Mag. N.	29 32·0	42	S.S.E.	1·885			
			Mag. N.S.	39 29·4	42	S.S.E.	1·878			
			Mag. S.	20 16·5	42	S.S.E.				
			wt. 1 gr.	11 33·4	42	S.S.E.	1·915			
			wt. 1½ gr.	17 36·2	42	S.S.E.	1·904			
			wt. 2 grs.	23 48·0	42	S.S.E.	1·917			
			wt. 2½ grs.	29 50·1	42	S.S.E.	1·918			
			wt. 3 grs.	36 40·9	42	S.S.E.	1·914			
			wt. 3½ grs.	44 52·1	42	S.S.E.	1·877			
	−58 44	213 11	Def. N.	35 11·8	42	S.S.E.	1·865			
			Def. S.	32 22·7	42	S.S.E.	1·882			
			Mag. N.	29 28·0	42	S.S.E.	1·891			
			Mag. N.S.	39 16·0	42	S.S.E.	1·896			
			Mag. S.	19 46·3	42	S.S.E.				
17.	−60 48	213 51	Def. N.	34 58·7	36	S.S.E.	1·878	—·016	1·892	Very slight motion, steering well.
			Def. S.	31 59·8	36	S.S.E.	1·905			
			Mag. N.	29 19·8	36	S.S.E.	1·903			
			Mag. N.S.	39 06·6	36	S.S.E.	1·907			
			Mag. S.	19 45·9	36	S.S.E.				
			wt. 1 gr.	11 51·7	36	S.S.E.	1·863			
			wt. 1½ gr.	16 49·6	36	S.S.E.	1·987			
			wt. 2 grs.	23 56·7	36	S.S.E.	1·907			
			wt. 2½ grs.	29 43·5	36	S.S.E.	1·923			
			wt. 3 grs.	36 48·8	36	S.S.E.	1·906			
			wt. 3½ grs.	44 22·1	36	S.S.E.	1·893			
	−61 37	213 54	Def. N.	34 28·6	34	S. ½ E.	1·908	—·016		
			Def. S.	31 43·6	34	S. ½ E.	1·922			
			Mag. N.	29 09·5	34	S. ½ E.	1·918			
			Mag. N.S.	39 10·2	34	S. ½ E.	1·903			
			Mag. S.	19 54·3	34	S. ½ E.				
18.	−62 34	212 34	Def. N.	34 27·6	32	S. by E.	1·909	—·016	1·916	Very steady, sailing amongst loose ice.
			Def. S.	31 38·4	32	S. by E.	1·928			
			Mag. N.	29 06·9	32	S. by E.	1·922			
			Mag. N.S.	38 39·3	32	S. by E.	1·945			
			Mag. S.	19 21·5	32	S. by E.				
			wt. 1 gr.	11 30·6	32	S. by E.	1·920			
			wt. 1½ gr.	16 59·2	32	S. by E.	1·968			
			wt. 2 grs.	23 55·7	32	S. by E.	1·905			
			wt. 2½ grs.	29 07·6	32	S. by E.	1·958			
			wt. 3 grs.	36 00·5	32	S. by E.	1·942			
			wt. 3½ grs.	43 45·9	32	S. by E.	1·920			
19.	−63 06	210 55	Def. N.	34 27·4	40	S.S.W.	1·910	—·015	1·910	Very steady, running amongst loose ice.
			Def. S.	31 50·7	40	S.S.W.	1·914			
			Mag. N.	29 08·0	40	S.S.W.	1·920			
			Mag. N.S.	38 52·6	40	S.S.W.	1·927			
			Mag. S.	19 37·4	40	S.S.W.				
20.	−63 36	208 20	Def. N.	34 20·3	34	S.S.W.	1·917			
			Def. S.	31 19·9	34	S.S.W.	1·946			
			Mag. N.	28 59·8	34	S.S.W.	1·932			
			Mag. N.S.	38 48·0	34	S.S.W.	1·933			
			Mag. S.	19 37·0	34	S.S.W.				
	−63 53	208 32	Def. N.	34 21·3	34	S.	1·916	—·014	1·927	Very steady, running amongst loose ice.
			Def. S.	31 23·0	34	S.	1·943			
			Mag. N.	28 47·5	34	S.	1·950			
			Mag. N.S.	38 39·1	34	S.	1·945			
			Mag. S.	19 21·6	34	S.				

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Dec. 21.	−64° 11′	206° 35′	Def. N.	34° 01′·3	34°	s.s.w.	1·936	—·013	1·927	Very steady, running amongst loose ice.
			Def. S.	31 15·8	34	s.s.w.	1·950			
			Mag. N.	28 54·2	34	s.s.w.	1·941			
			Mag. N.S.	38 44·7	34	s.s.w.	1·937			
			Mag. S.	19 15·2	34	s.s.w.				
	−64 51	206 19	wt. 1 gr.	11 10·3	35	s. ¾ w.	1·978	—·013	1·943	Very steady, steering amongst loose ice.
			wt. 1½ gr.	17 10·4	35	s. ¾ w.	1·948			
			wt. 2 grs.	23 07·5	35	s. ¾ w.	1·968			
			wt. 2½ grs.	29 07·7	35	s. ¾ w.	1·959			
			wt. 3 grs.	35 52·4	35	s. ¾ w.	1·949			
			wt. 3½ grs.	42 59·5	35	s. ¾ w.	1·947			
			Def. N.	34 05·5	35	s. ¾ w.	1·932			
			Def. S.	31 01·8	35	s. ¾ w.	1·965			
22.	−65 19	205 08	Def. N.	34 07·6	37	s. ½ w.	1·930	—·013	1·931	Very steady, steering amongst loose ice.
			Def. S.	31 17·5	37	s. ½ w.	1·948			
			Mag. N.	28 50·9	37	s. ½ w.	1·945			
			Mag. N.S.	38 42·3	37	s. ½ w.	1·940			
			Mag. S.	19 29·9	37	s. ½ w.				
	−65 34	205 00	Def. N.	33 59·5	37	s.	1·937			
			Def. S.	31 00·9	37	s.	1·966			
			Mag. N.	28 53·2	37	s.	1·942			
			Mag. N.S.	38 37·7	37	s.	1·946			
			Mag. S.	19 25·2	37	s.				
23.	−65 47	204 19	Def. N.	34 02·2	36	N.E.	1·935	+·009	1·950	Very steady, sailing amongst loose ice.
			Def. S.	31 23·8	36	N.E.	1·942			
			Mag. N.	28 42·6	36	N.E.	1·958			
			Mag. N.S.	38 44·3	36	N.E.	1·938			
			Mag. S.	19 44·9	36	N.E.				
24.	−65 54	204 08	Def. N.	34 15·9	42	N. by w.	1·921	+·011		Fast to a piece of ice.
			Def. S.	31 21·8	42	N. by w.	1·944			
			Mag. N.	28 51·3	42	N. by w.	1·945			
			Mag. N.S.	38 45·8	42	N. by w.	1·936			
			Mag. S.	19 29·0	42	N. by w.				
27.	−66 08	203 50	Def. N.	34 07·9	30	E.S.E.	1·929	—·004	1·949	Working in a hole of water.
			Def. S.	30 57·8	30	E.S.E.	1·969			
			Mag. N.	28 46·1	30	N.W. by N.	1·953	+·010		
			Mag. N.S.	38 45·3	30	N.W. by N.	1·937			
			Mag. S.	19 24·3	30	N.W. by N.				
28.	−66 10	202 54	Def. N.	33 56·0	30	w. by N.	1·941	+·003		
1842. Jan. 1.	−66 36	203 29	Def. N.	34 06·6	44	N.W. ½ w.	1·931	+·009	1·961	Fast to a piece of ice, Erebus fifty yards N.E. (This result is not employed in the map.)
			Def. S.	31 17·7	44	N.W. ½ w.	1·948			
			Mag. N.	28 46·6	44	N.W. ½ w.	1·951			
			Mag. N.S.	38 35·1	44	N.W. ½ w.	1·950			
			Mag. S.	19 28·8	44	N.W. ½ w.				
			wt. 1 gr.	11 20·8	44	N.W. ½ w.	1·950			
			wt. 1½ gr.	16 59·2	44	N.W. ½ w.	1·967			
			wt. 2 grs.	22 44·6	44	N.W. ½ w.	2·001			
			wt. 2½ grs.	29 21·5	44	N.W. ½ w.	1·947			
			wt. 3 grs.	35 50·3	44	N.W. ½ w.	1·952			
			wt. 3½ grs.	43 33·7	44	N.W. ½ w.	1·922			
7.	−66 20	203 39	Def. N.	34 13·5	33	N.W.	1·924	+·009	1·944	Working in a hole of water.
			Def. S.	31 20·0	33	N.W.	1·946			
			Mag. N.	29 00·1	33	N.W.	1·932			
			Mag. N.S.	38 40·2	33	N.W.	1·943			
			Mag. S.	19 29·8	33	N.W.				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Jan. 8.	−66° 05′	204° 02′	Def. N.	34° 13·8′	35°	s. by w. ½ w.	1·923	−·011	1·944	Working in a hole of water.
			Def. S.	31 22·2	35	s. by w. ½ w.	1·944			
			Mag. N.	29 05·0	35	s. by w. ½ w.	1·925			
			Mag. N.S.	38 47·0	35	s. by w. ½ w.	1·935			
			Mag. S.	19 29·8	35	s. by w. ½ w.				
			wt. 1 gr.	11 14·4	35	N.	1·965	+·012		
			wt. 1½ gr.	17 07·6	35	N.	1·951			
			wt. 2 grs.	23 02·1	35	N.	1·982			
			wt. 2½ grs.	29 01·7	35	N.	1·963			
			wt. 3 grs.	35 44·9	35	N.	1·953			
			wt. 3½ grs.	43 14·8	35	N.	1·930			
9.	−66 01	204 04	Def. N.	33 45·1	35	s.w. ½ w.	1·952	−·007		
			Def. S.	31 12·7	35	s.w.	1·954			
			Mag. N.	28 59·9	35	s.w. by w.	1·932			
			Mag. N.S.	38 37·6	35	s.w. by w.	1·946			
			Mag. S.	19 16·0	35	s.w. by w.				
10.	−65 57	203 56	Def. N.	33 53·7	30	w. by s.	1·943	·000	1·949	Working in a hole of water.
			Def. S.	30 59·0	30	w. by s.	1·968			
			Mag. N.	28 46·5	30	w. by s.	1·952			
			Mag. N.S.	38 36·3	30	E.	1·948	+·001		
			Mag. S.	19 16·3	30	E.				
			wt. 1 gr.	11 28·5	30	w. by s. ½ s.	1·923	−·003		
			wt. 1½ gr.	16 59·9	30	w. by s. ½ s.	1·965			
			wt. 2 grs.	22 55·0	30	w. by s. ½ s.	1·984			
			wt. 2½ grs.	29 09·5	30	w. by s. ½ s.	1·955			
			wt. 3 grs.	35 46·6	30	w. by s. ½ s.	1·950			
			wt. 3½ grs.	42 54·2	30	w. by s. ½ s.	1·942			
			Def. N.	33 54·5	30	s.w. by w.	1·942	−·006		
			Def. S.	31 22·4	30	s.w. by w.	1·944			
			Mag. N.	28 46·7	30	s.w. by w.	1·952			
			Mag. N.S.	38 30·3	30	s.w. by w.	1·957			
			Mag. S.	19 19·4	30	s.w. by w.				
11.	−65 56	203 31	Def. N.	33 51·4	30	s.	1·946	−·012	1·945	Working in a hole of water.
			Def. S.	31 05·2	30	s.	1·962			
			Mag. N.	28 45·2	30	s.	1·953			
			Mag. N.S.	38 40·3	30	s.	1·943			
			Mag. S.	19 21·0	30	s.				
13.	−66 06	202 10	Def. N.	34 14·7	33	N. ½ E.	1·922	+·012		
			Def. S.	31 23·1	33	N. ½ E.	1·943			
			Mag. N.	28 52·6	33	N. ½ E.	1·942			
			Mag. N.S.	38 49·4	33	N. ½ E.	1·931			
			Mag. S.	19 36·1	33	N. ½ E.				
14.	−66 08	201 46	Def. N.	34 10·3	33	N.E. by E.	1·927	+·008		
			Def. S.	31 15·2	35	N.E. by E.	1·951			
			Mag. N.	28 49·5	35	N.E. by E.	1·947			
			Mag. N.S.	38 38·4	35	N.E. by E.	1·946			
			Mag. S.	19 27·1	35	N.E. by E.				
16.	−65 47	202 08	Def. N.	33 47·6	50	Observed on ice.	1·949	……	1·948	
			Def. S.	31 16·1	50		1·951			
			Mag. N.	28 52·7	50		1·942			
			Mag. N.S.	38 45·7	50		1·936			
			Mag. S.	19 44·8	50					
			wt. 1 gr.	11 25·4	50		1·940			
			wt. 1½ gr.	17 08·3	50		1·957			
			wt. 2 grs.	23 02·9	50		1·979			
			wt. 2½ grs.	29 16·2	50		1·955			
			wt. 3 grs.	36 17·4	50		1·935			
			wt. 3½ grs.	43 23·5	50		1·932			

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Jan. 26.	−67° 12′	203° 12′	Def. N.	33° 14′·0	35°	E. by N.	1·984	+·003	1·972*	Fast to a piece of ice: Erebus N. by W. 20 fathoms*.
			Def. S.	31 00·0	35	E. by N.	1·967			
			Mag. N.	28 30·9	35	E. by N.	1·977			
			Mag. N.S.	38 28·5	35	E. by N.	1·960			
			Mag. N.S.	38 22·2	35	S.E. by S.	1·966	−·009		Fast to a piece of ice: Erebus N.E. by E.
			Mag. S.	19 15·7	35	S.E. by S.				
28.	−67 46	204 17	Def. N.	33 47·7	35	E. by N.	1·949	+·003	1·960	A swell from W.S.W., table steady.
			Def. S.	31 00·7	35	N.	1·966	+·012		
			Def. N.	33 47·5	35	N. by E.	1·949	+·011		
			Def. N.	33 43·8	35	N.N.E.	1·954	+·010		
			Mag. N.	28 45·1	35	N.N.E.	1·955			
			Mag. N.S.	38 29·8	35	N.N.E.	1·957			
			Mag. S.	19 21·1	35	N.N.E.				
			Def. N.	33 45·2	35	S. ¾ W.	1·952	−·012		
			Def. S.	30 52·2	35	S. ¾ W.	1·975			
			Mag. N.	28 39·0	35	S. ¾ W.	1·965			
			Mag. N.S.	38 22·4	35	S. ¾ W.	1·968			
			Mag. S.	19 16·9	35	S. ¾ W.				
28.	−67 46	204 17	wt. 1 gr.	10 53·5	35	N.	2·028	+·012	1·965	Table steady.
			wt. 1½ gr.	16 57·2	35	N.	1·972			
			wt. 2 grs.	23 09·2	35	N. by W. ¾ W.	1·966	+·011		
			wt. 2½ grs.	29 14·4	35	N. by W. ¾ W.	1·951			
			wt. 3 grs.	35 37·6	35	N. by W. ¾ W.	1·959			
			wt. 3½ grs.	42 53·4	35	N. by W. ¾ W.	1·944			
29.	−67 24	204 05	Def. N.	33 42·1	31	S. by W.	1·956	−·012		
			Def. S.	30 58·3	31	S. by W.	1·969			
			Mag. N.	28 49·8	31	S. by W.	1·947			
			Mag. N.S.	38 41·5	31	S. by W.	1·941			
31.	−67 12	202 24	Def. N.	33 51·2	32	S.S.W.	1·946	−·011	1·946	Strong breeze, table steady.
			Def. S.	30 50·5	32	S.S.W.	1·976			
			Mag. N.	28 38·1	32	S.S.W.	1·966			
			Mag. N.S.	38 30·3	32	S.S.W.	1·957			
			Mag. S.	19 21·8	32	S.S.W.				
			Def. N.	33 52·1	32	S.W.	1·945	−·007		
			Def. N.	33 52·3	32	S.W. by S.	1·945	−·008		
Feb. 1.	−67 12	201 34	Def. N.	34 30·6	32	W. by S.	1·906	−·001	1·935	Table very steady.
			Def. N.	34 04·4	32	E.	1·933	+·001		
	−67 16		Def. N.	33 56·0	32	S.S.W.	1·941	−·011		
			Def. S.	31 03·0	32	S.S.W.	1·964			
			Mag. N.	28 46·3	32	S.S.W.	1·951			
			Mag. N.S.	38 31·8	32	S.S.W.	1·954			
			Mag. S.	19 21·1	32	S.S.W.				
			Def. N.	34 07·1	32	N. ¾ W.	1·930	+·011		
			Def. N.	33 51·1	32	S.W.	1·946	−·007		
2.	−67 56	199 48	Def. N.	33 33·9	31	S. by W.	1·964	−·011	1·955	Cross sea ship unsteady.
			Def. S.	31 00·5	31	S. by W.	1·966			
			Mag. N.	28 51·5	31	S. by W.	1·944			
			Mag. N.S.	38 23·3	31	S. by W.	1·967			
			Mag. S.	19 15·5	31	S. by W.				
3.	−68 21	200 06	Def. N.	33 45·4	31	S.S.W.	1.952	−·011		
			Def. S.	30 51·4	31	S.S.W.	1·976			
			Mag. N.	28 22·2	31	S.S.W.	1·990			
			Mag. N.S.	38 21·2	31	S.S.W.	1·970			
			Mag. S.	19 13·8	31	S.S.W.				

* This result has not been employed in the map.

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Feb. 4.	−68° 45′	199° 41′	Def. N.	33° 38′·7	30°	s.	1·959	—·011	1·961	Table steady.
			Def. S.	30 43·2	30	s.	1·984			
			Mag. N.	28 32·2	30	s.	1·975			
			Mag. N.S.	38 15·0	30	s.	1·977			
			Mag. S.	19 15·9	30	s.				
			wt. 1 gr.	11 08·5	30	s.	1·984			
			wt. 1½ gr.	16 55·4	30	s. ½ E.	1·974	—·011		
			wt. 2 grs.	22 31·5	30	s.	2·015	—·011		
			wt. 2½ grs.	29 00·9	30	s.	1·963			
			wt. 3 grs.	35 06·1	30	s.	1·983			
			wt. 3½ grs.	42 35·6	30	s. by E.	1·952	—·011		
			Def. N.	33 38·8	30	s. by E.	1·959			
			Def. S.	31 04·3	30	s. by E.	1·963			
	−68 49	199 26	Def. N.	33 59·1	30	N.N.W.	1·938	+·010		
5.	−68 52	198 24	Def. N.	33 46·1	32	s.w.	1·952	—·006	1·966	Fresh breeze, table steady.
			Def. S.	30 46·1	32	s.w.	1·981			
			Mag. N.	28 35·2	32	s.w.	1·970			
			Mag. N.S.	38 24·0	32	s.w.	1·965			
			Mag. S.	19 18·6	32	s.w.				
			wt. 1 gr.	11 08·8	32	s.w. ½ w.	1·984	—·005		
			wt. 1½ gr.	16 59·2	32	s.w. ½ w.	1·966			
			wt. 2 grs.	22 30·9	32	s.w. ½ w.	2·016			
			wt. 2½ grs.	28 49·9	32	s.w. ½ w.	1·974			
			wt. 3 grs.	35 33·8	32	s.w. ½ w.	1·961			
			wt. 3½ grs.	42 40·2	32	s.w. ½ w.	1·949			
6.	−69 55	192 17	Def. N.	33 46·5	34	s. by w.	1·952	—·010	1·965	A swell from the N.N.W., unsteady.
			Def. S.	30 44·6	34	s. by w.	1·982			
			Mag. N.	28 21·7	34	s. by w.	1·990			Steering well.
			Mag. N.S.	38 08·0	34	s. by w.	1·987			
			Mag. S.	18 54·1	34	s. by w.				
			Def. N.	33 44·5	34	s.	1·953	—·010		
7.	−70 05	191 03	Def. N.	33 53·9	30	s.s.w.	1·943	—·009		Swell from W.N.W., steering badly, very unsteady.
			Def. S.	30 47·4	30	s.s.w.	1·980			
			Mag. N.	28 38·8	30	s.s.w.	1·965			
			Mag. N.S.	37 43·3	30	s.s.w.	2·021			
			Mag. S.	17 52·3	30	s.s.w.				
8.	−70 08	186 39	Def. N.	33 48·7	31	s.w.	1·948	—·004	1·976	Steering wildly, unsteady.
			Def. N.	33 49·3	31	s.w. by w.	1·947			
			Def. S.	30 38·2	31	s.w. by w.	1·989			
			Mag. N.	28 30·9	31	s.w. by w.	1·977			
			Mag. N.S.	37 43·8	31	s.w. by w.	2·020			
			Mag. S.	17 38·4	31	s.w. by w.				Table steady.
	−70 17	186 04	wt. 1 gr.	11 15·2	31	s.	1·961	—·009		
			wt. 1½ gr.	16 52·1	31	s.	1·979			
			wt. 2 grs.	22 37·0	31	s.	2·007			
			wt. 2½ grs.	28 35·7	31	s.	1·989			
			wt. 3 grs.	34 59·8	31	s.	1·988			
			wt. 3½ grs.	41 52·3	31	s.	1·980			
			Def. N.	33 38·4	31	s.	1·960			
			Def. S.	30 34·2	31	s.	1·995			
			Mag. N.	28 26·8	31	s.	1·983			
			Mag. N.S.	37 33·2	31	s.	2·034			
			Mag. S.	17 17·7	31	s.				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Feb. 19.	−76° 48′	184° 46′	Def. N.	33° 16′·1	25°	N. by E.	1·983	+·006	2·009	Head sea, ship unsteady.
			Def. S.	30 30·3	25	N. by E.	1·997			
			Mag. N.	28 14·8	25	N. by E.	2·002			
			Mag. N.S.	37 34·7	25	N. by E.	2·031			
			Mag. S.	17 30·6	25	N. by E.				
20.	−76 20	191 26	Def. N.	33 10·8	28	N.E.	1·988	+·005	2·024	Head sea, ship unsteady.
			Def. S.	30 30·9	28	N.E.	1·996			
			Mag. N.	27 55·8	28	N.E.	2·030			
			Mag. N.S.	37 12·8	28	N.E.	2·062			
			Mag. S.	17 14·3	28	N.E.				
22.	−76 24	184 54	Def. N.	33 09·1	30	S.E. by S.	1·990	—·005	2·004	Strong wind, head sea, unsteady.
			Def. S.	30 25·3	30	S.E. by S.	2·002			
			Mag. N.	28 11·1	30	S.E. by S.	2·007			
			Mag. N.S.	37 30·2	30	S.E. by S.	2·039			
			Mag. S.	17 41·0	30	S.E. by S.				
	−77 13	193 52	Def. N.	33 12·9	30	E. by S.	1·986	·000	2·011	Light swell, motio gentle.
			Def. S.	30 39·5	30	E. by S.	1·987			
			Mag. N.	28 21·0	30	E. by S.	1·991			
			Mag. N.S.	37 31·9	30	E. by S.	2·036			
			Mag. S.	17 13·0	30	E. by S.				
			wt. 1 gr.	10 55·0	30	E. by S.	2·021			
			wt. 1½ gr.	16 28·5	30	E. by S.	2·026			
			wt. 2 grs.	22 23·3	30	E. by S.	2·028			
			wt. 2½ grs.	28 07·5	30	E. by S.	2·020			
			wt. 3 grs.	34 16·6	30	E. by S.	2·025			
			wt. 3½ grs.	41 32·7	30	E. by S.	1·992			
23.	−77 47	197 25	Def. N.	33 28·8	29	N.E. by E.	1·969	+·005	2·001	Table steady.
			Def. S.	30 36·2	29	N.E. by E.	1·991			
			Mag. N.	28 08·2	29	E.N.E.	2·011	+·004		
			Mag. N.S.	37 45·3	29	E.N.E.	2·018			
			Mag. S.	17 17·8	29	E.N.E.				
24.	−77 14	199 29	Def. N.	33 10·3	30	S.W. by S.	1·989	—·005	1·992	Fresh breeze, from N.E. steady.
			Def. S.	30 41·2	30	S.W. by S.	1·980			
			Mag. N.	28 22·9	30	S.W. by S.	1·989			
			Mag. N.S.	37 30·5	30	S.W. by S.	2·038			
			Mag. S.	17 25·3	30	S.W. by S.				
			wt. 1 gr.	11 02·2	30	S.W. by S.	2·000			
			wt. 1½ gr.	16 31·1	30	S.W. by S.	2·020			
			wt. 2 grs.	22 33·5	30	S.W. by S.	2·010			
			wt. 2½ grs.	28 40·4	30	S.W. by S.	1·983			
			wt. 3 grs.	34 58·0	30	S.W. by S.	1·989			
			wt. 3½ grs.	42 08·1	30	S.W. by S.	1·970			
25.	−75 20	194 36	Def. N.	33 05·2	29	W.	1·994	+·001	2·003	Fresh bre from N steady.
			Def. S.	30 34·4	29	W.	1·993			
			Mag. N.	28 14·8	29	W.	2·000			
			Mag. N.S.	37 43·8	29	W.	2·020			
			Mag. S.	17 38·2	29	W.				
26.	−73 10	189 21	Def. N.	33 17·7	29	N.W. by W.	1·980	+·005	2·000	Strong tion
			Def. S.	30 34·9	29	N.W. by W.	1·992			
			Mag. N.	28 06·6	29	N.W. by W.	2·012			
			Mag. N.S.	38 01·7	29	N.W. by W.	1·995			
			Mag. S.	17 13·8	29	N.W. by W.				
27.	−72 03	187 40	Def. N.	33 22·8	26	S.W.	1·976	—·005	1·999	East m
			Def. S.	30 36·3	26	S.W.	1·991			
			Mag. N.	28 11·4	26	S.W.	2·007			
			Mag. N.S.	37 39·4	26	W. by N. ½ N.	2·025	+·002		
			Mag. S.	17 28·8	26	W. by N. ½ N.				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Feb. 27.	−72° 03′	187° 40′	wt. 1 gr.	11° 01′·0	26°	S.W. ½ W.	2·002	−·005	1·999	Easterly swell, slight motion.
			wt. 1½ gr.	16 26·3	26	S.W. ½ W.	2·029			
			wt. 2 grs.	22 13·8	26	S.W. ½ W.	2·040			
			wt. 2½ grs.	28 25·7	26	S.W. ½ W.	1·998			
			wt. 3 grs.	34 35·3	26	S.W. ½ W.	2·009			
			wt. 3½ grs.	42 33·7	26	S.W. ½ W.	1·953			
	−71 43	187 15	wt. 1 gr.	11 04·8	26	W. by N. ½ N.	1·990	+·002	1·999	Easterly swell, slight motion.
			wt. 1½ gr.	16 01·3	26	W. by N. ½ N.	2·081			
			wt. 2 grs.	22 29·5	26	W. by N. ½ N.	2·016			
			wt. 2½ grs.	28 37·6	26	W. by N. ½ N.	1·986			
			wt. 3 grs.	34 56·6	26	W. by N. ½ N.	1·990			
			wt. 3½ grs.	42 04·9	26	W. by N. ½ N.	1·971			
28.	−71 20	184 30	Def. N.	33 44·8	25	W. by S.	1·952	·000		
			Def. S.	30 47·1	25	W. by S.	1·980			
			Mag. N.	28 22·8	25	W. by S.	1·988			
			Mag. N.S.	37 39·1	25	W. by S.	2·025			
			Mag. S.	17 44·3	25	W. by S.				
Mar. 1.	−69 54	179 55	Def. N.	33 24·5	32	W.N.W.	1·974	+·005	1·999	Easterly swell, slight motion.
			Def. S.	30 38·5	32	W.N.W.	1·989			
			Mag. N.	28 17·3	32	W.N.W.	1·998			
			Mag. N.S.	37 47·1	32	W.N.W.	2·015			
			Mag. S.	17 43·2	32	W.N.W.				
2.	−68 09	183 10	Def. N.	33 34·6	32	N.N.E.	1·963	+·007	1·981	Swell from eastward.
			Def. S.	31 01·2	32	N.N.E.	1·966			
			Mag. N.	28 30·9	32	N.N.E.	1·977			
			Mag. N.S.	38 05·3	32	N.N.E.	1·990			
			Mag. S.	18 05·9	32	N.N.E.				
3.	−67 35	185 18	Def. N.	33 30·0	31	N.E. by E.	1·968	+·006	1·978	Cross sea, ship unsteady.
			Def. S.	31 15·6	31	N.E. by E.	1·951			
			Mag. N.	28 29·3	31	N.E. by E.	1·979			
			Mag. N.S.	37 54·8	31	N.E. by E.	2·005			
			Mag. S.	18 00·1	31	N.E. by E.				
			wt. 1 gr.	11 07·4	31	N.E. by E.	1·986			
			wt. 1½ gr.	17 00·0	31	N.E. ½ E.	1·965	+·006		
			wt. 2 grs.	22 48·2	31	N.E. ½ E.	1·993			
			wt. 2½ grs.	28 54·6	31	N.E. ½ E.	1·970			
			wt. 3 grs.	35 30·5	31	N.E. ½ E.	1·965			
			wt. 3½ grs.	42 54·1	31	N.E. ½ E.	1·942			
4.	−67 40	187 40	Def. N.	33 43·9	33	N. by W.	1·954	+·011	1·981	Strong gale, heavy sea, ship unsteady.
			Def. S.	31 04·0	33	N. by W.	1·963			
			Mag. N.	28 23·5	33	N. by W.	1·988			
			Mag. N.S.	37 47·2	33	N. by W.	2·015			
			Mag. S.	17 59·9	33	N. by W.				
5.	−67 09	188 02	Def. N.	33 43·6	35	N.	1·954	+·012		
			Def. S.	31 47·7	35	N.	1·917			
			Mag. N.	28 36·4	35	N.	1·968			
			Mag. N.S.	37 57·1	35	N.	2·003			
			Mag. S.	17 50·3	35	N.				
6.	−65 28	191 24	Def. N.	33 56·8	33	N. by E.	1·940	+·012	1·955	Heavy sea from W.S.W., ship very unsteady.
			Def. S.	31 20·9	33	N. by E.	1·945			
			Mag. N.	28 44·3	33	N. by E.	1·956			
			Mag. N.S.	38 07·4	33	N. by E.	1·988			
			Mag. S.	18 29·3	33	N. by E.				
	−64 49	192 21	wt. 1 gr.	11 29·7	33	N. by E. ½ E.	1·920	+·012		Swell from the S.S.W., table steady.
			wt. 1½ gr.	17 20·6	33	N. by E. ½ E.	1·928			
			wt. 2 grs.	23 10·9	33	N. by E. ½ E.	1·963			

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Mar. 6.	−64° 49′	192° 21′	wt. 2½ grs.	29° 34′·9	33°	N. by E. ½ E.	1·930	+·012	1·955	Swell from the S.S.W., table steady.
			wt. 3 grs.	36 02·8	33	N. by E. ½ E.	1·940			
			wt. 3½ grs.	43 37·5	33	N. by E. ½ E.	1·917			
7.	−63 30	194 15	Def. N.	34 42·3	33	N. by E.	1·895	+·012	1·942	Table steady.
			Def. S.	31 50·8	33	N. by E.	1·914			
			Mag. N.	29 04·3	33	N. by E.	1·926			
			Mag. N.S.	38 11·2	33	N. by E.	1·983			
			Mag. S.	18 24·5	33	N. by E.				
8.	−62 17	195 55	Def. N.	34 47·8	35	N. by E.	1·889	+·014		
			Def. S.	32 05·4	35	N. by E.	1·900			
			Mag. N.	29 00·5	35	N. by E.	1·931			
			Mag. N.S.	38 35·2	35	N. by E.	1·950			
			Mag. S.	18 46·6	35	N. by E.				
			wt. 1 gr.	11 47·0	35	N. by E.	1·875		1·916	Table steady.
			wt. 1½ gr.	18 01·9	35	N. by E.	1·857			
			wt. 2 grs.	23 47·3	35	N. by E.	1·916			
			wt. 2½ grs.	30 03·9	35	N. by E.	1·902			
			wt. 3 grs.	37 04·3	35	N. by E.	1·894			
			wt. 3½ grs.	45 00·2	35	N. by E.	1·870			
9.	−61 06	198 08	Def. N.	34 50·2	35	N.E. ½ N.	1·887	+·013		Sea getting up, unsteady.
			Def. S.	32 03·8	35	N.E. ½ N.	1·901			
			Mag. N.	29 15·0	35	N.E. ½ N.	1·910			
			Mag. N.S.	38 35·4	35	N.E. ½ N.	1·950			
			Mag. S.	18 55·7	35	N.E. ½ N.				
10.	−60 19	203 42	Def. N.	34 45·6	34	E.N.E.	1·891	+·010	1·920	Ship unsteady.
			Def. S.	32 05·7	34	E.N.E.	1·899			
			Mag. N.	29 15·1	34	E.N.E.	1·910			
			Mag. N.S.	38 40·9	34	E.N.E.	1·942			
			Mag. S.	19 00·8	34	E.N.E.				
11.	−60 15	208 06	Def. N.	35 04·8	35	E. by N.	1·872	+·007	1·907	Strong gale, heavy sea, ship very unsteady.
			Def. S.	31 58·7	35	E. by N.	1·906			
			Mag. N.	29 04·3	35	E. by N.	1·926			
			Mag. N.S.	38 46·5	35	E. by N.	1·935			
			Mag. S.	18 53·1	35	E. by N.				
12.	60 16	211 45	Def. N.	35 04·2	35	E. by N.	1·873			Heavy swell from S.W., unsteady.
			Def. S.	32 08·0	35	E. by N.	1·897			
			Mag. N.	29 25·5	35	E. by N.	1·894			
			Mag. N.S.	39 14·9	35	E. by N.	1·897			
			Mag. S.	18 53·3	35	E. by N.				
13.	−59 53	216 28	Def. N.	35 00·2	36	N.E. ½ E.	1·877	+·015	1·910	Heavy swell, ste ing badly.
			Def. S.	32 11·9	36	N.E. ½ E.	1·893			
			Mag. N.	29 23·2	36	N.E. ½ E.	1·898			
			Mag. N.S.	39 02·3	36	N.E. ½ E.	1·914			
			Mag. S.	18 59·1	36	N.E. ½ E.				
14.	−59 22	218 14	Def. N.	35 07·5	37	N.E. ½ E.	1·870	+·015	1·900	Heavy swell, unsteady, s ing badly.
			Def. S.	32 32·6	37	N.E. ½ E.	1·871			
			Mag. N.	29 36·2	37	N.E. ½ E.	1·879			
			Mag. N.S.	38 56·5	37	N.E. ½ E.	1·922			
			Mag. S.	19 00·9	37	N.E. ½ E.				
15.	−58 49	221 25	Def. N.	35 14·8	37	E.N.E.	1·862	+·011	1·913	Heavy swel ing badl
			Def. S.	31 38·8	37	E.N.E.	1·927			
			Mag. N.	29 10·9	37	E.N.E.	1·917			
			Mag. N.S.	39 11·3	37	E.N.E.	1·902			
			Mag. S	19 05·6	37	E.N.E.				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Mar. 16.	−59° 01′	227° 43′	Def. N.	34° 39′·9	39°	E.	1·897	+·003	1·897	Heavy swell, steering badly.
			Def. S.	32 14·2	39	E.	1·891			
			Mag. N.	29 30·9	39	E.	1·887			
			Mag. N.S.	39 10·7	39	E.	1·903			
			Mag. S.	18 51·8	39	E.				
18.	−60 05	235 56	Def. N.	35 07·2	38	E. by S.	1·870	·000	1 884	Heavy sea from S.W. by W., ship unsteady.
			Def. S.	32 36·0	38	E. by S.	1·868			
			Mag. N.	29 27·6	38	E. by S.	1·892			
			Mag. N.S.	39 08·7	38	E. by S.	1·904			
			Mag. S.	18 50·6	38	E. by S.				
	−60 17	236 38	Def. N.	35 02·5	38	E.	1·875	+·003	1·892	The ship more steady.
			Def. S.	32 29·4	38	E.	1·875			
			Mag. N.	29 25·4	38	E.	1·896			
			Mag. N.S.	39 04·2	38	E.	1·911			
			Mag. S.	18 45·3	38	E.				
	−60 24	237 29	Def. N.	35 05·5	38	E. by N.	1·872	+·007	1·907	Ship steady.
			Def. S.	32 07·2	38	E. by N.	1·898			
			Mag. N.	29 06·3	38	E. by N.	1·923			
			Mag. N.S.	39 05·9	38	E. by N.	1·909			
			Mag. S.	18 23·6	38	E. by N.				
21.	−59 05	247 27	Def. N.	35 50·2	38	E. by N.	1·830	+·007	1·875	Cross sea, motion gentle.
			Def. S.	32 49·7	38	E. by N.	1·853			
			Mag. N.	29 27·6	38	E. by N.	1·892			
			Mag. N.S.	39 13·5	38	E. by N.	1·898			
			Mag. S.	19 10·0	38	E. by N.				
22.	−58 26	251 42	Def. N.	35 29·5	38	E. by N.	1·848	+·007	1·885	Cross sea, ship unsteady.
			Def. S.	32 41·7	38	E. by N.	1·862			
			Mag. N.	29 27·9	38	E. by N.	1·891			
			Mag. N.S.	39 05·7	38	E. by N.	1·909			
			Mag. S.	19 23·5	38	E. by N.				
23.	−58 33	254 45	wt. 1 gr.	12 12·4	33	E. ½ N.	1·812	+·006	1·824	Little motion.
			wt. 1½ gr.	18 20·0	33	E. ½ N.	1·828			
			wt. 2 grs.	25 22·7	33	E. ½ N.	1·803			
			wt. 2½ grs.	31 29·0	33	E. ½ N.	1·825			
			wt. 3 grs.	39 04·8	33	E. ½ N.	1·812			
			wt. 3½ grs.	47 40·6	33	E. ½ N.	1·780			
			Def. N.	36 13·8	33	E. ½ N.	1·806			
			Def. S.	33 24·9	33	E. ½ N.	1·818			
			Mag. N.	29 55·5	33	E. ½ N.	1·850			
			Mag. N.S.	39 49·9	33	E. ½ N.	1·851			
			Mag. S.	19 52·7	33	E. ½ N.				
24.	−58 40	257 32	Def. N.	36 09·9	35	E. by N.	1·810	+·010	1·832	Little motion.
			Def. S.	33 27·9	35	E. by N.	1·815			
			Mag. N.	29 47·9	35	E. by N.	1·862			
			Mag. N.S.	39 36·0	35	E. by N.	1·869			
			Mag. S.	19 56·5	35	E. by N.				
	−58 53	258 55	wt. 1 gr.	12 30·1	35	E. by N.	1·770			Little motion; overcast and damp.
			wt. 1½ gr.	18 17·1	35	E. by N.	1·837			
			wt. 2 grs.	25 22·4	35	E. by N.	1·803			
			wt. 2½ grs.	31 46·5	35	E. by N.	1·810			
26.	−58 59	267 50	Def. N.	36 48·2	45	E. by N. ½ N.	1·773	+·012	1·783	Motion gentle.
			Def. S.	34 31·2	45	E. by N. ½ N.	1·753			
			Mag. N.	30 53·2	45	E. by N. ½ N.	1·771			
			Mag. N.S.	40 39·9	45	E. by N. ½ N.	1·786			
			Mag. S.	20 37·6	45	E. by N. ½ N.				

Observations of the Magnetic Force. (Continued.)

1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Mar. 27.	−59° 01′	272° 06′	Def. N.	37° 29′·4	36°	E.N.E.	1·734	+·013	1·747	Ship unsteady.
			Def. S.	35 37·2	36	E.N.E.	1·687			
			Mag. N.	31 21·2	36	E.N.E.	1·734			
			Mag. N.S.	40 47·4	36	E.N.E.	1·780			
			Mag. S.	20 48·3	36	E.N.E.				
28.	−58 24	276 18	Def. N.	38 14·0	39	N.E. by E.	1·690	+·016	1·722	Swell from S.W., slight motion.
			Def. S.	35 38·0	39	N.E. by E.	1·686			
			Mag. N.	31 57·2	39	N.E. by E.	1·684			
			Mag. N.S.	40 59·0	39	N.E. by E.	1·763			
			Mag. S.	20 51·8	39	N.E. by E.				
29.	−58 25	279 44	wt. 1 gr.	13 14·6	45	N.E. by E.	1·676	+·017	1·672	Slight motion.
			wt. 1½ gr.	20 00·5	45	N.E. by E.	1·684			
			wt. 2 grs.	28 08·5	45	N.E. by E.	1·642			
			wt. 2½ grs.	36 37·1	45	N.E. by E.	1·601			Needle very unsteady (omitted in the mean).
			Def. N.	38 49·8	45	N.E. by E.	1·656			Slight motion.
			Def. S.	36 09·1	45	N.E. by E.	1·658			
			Mag. N.	32 21·1	45	N.E. by E.	1·651			
			Mag. N.S.	41 45·0	45	N.E. by E.	1·705			
			Mag. S.	21 53·0	45	N.E. by E.				
30.	−58 31	281 33	Def. N.	38 25·5	40	E.N.E.	1·680	+·015		
			Def. S.	36 04·1	40	E.N.E.	1·661			
			Mag. N.	32 15·8	40	E.N.E.	1·658			
			Mag. N.S.	41 37·5	40	E.N.E.	1·714			
			Mag. S.	21 26·3	40	E.N.E.				
31.	−58 36	285 33	Def. N.	39 35·3	44	N.E.	1·611	+·021	1·648	Slight motion.
			Def. S.	36 46·6	44	N.E.	1·619			
			Mag. N.	32 48·3	44	N.E.	1·613			
			Mag. N.S.	42 15·6	44	N.E.	1·664			
			Mag. S.	22 13·4	44	N.E.				
Apr. 1.	−57 21	289 36	Def. N.	40 12·8	47	N.E. by N.	1·573	+·024	1·592	Strong breeze, ship unsteady, steering wild.
			Def. S.	36 33·8	47	N.E. by N.	1·632			
			Mag. N.	33 28·9	47	N.E. by N.	1·554			
			Mag. N.S.	42 50·4	47	N.E. by N.	1·622			
			Mag. S.	22 29·8	47	N.E. by N.				
2.	−57 26	291 32	Def. N.	40 13·1	44	S.E.	1·573	−·017		Heavy sea, ship unsteady.
			Def. S.	37 44·6	44	S.E.	1·561			
			Mag. N.	33 23·9	44	S.E.	1·562			
			Mag. N.S.	42 47·3	44	S.E.	1·627			
			Mag. S.	23 07·7	44	S.E.				
3.	−56 37	294 34	Def. N.	41 28·4	44	N.E.	1·505	+·022	1·495	Heavy sea, ship unsteady.
			Def. S.	38 40·8	44	N.E.	1·506			
			Mag. N.	33 47·9	44	N.E.	1·527			
			Mag. N.S.	44 02·5	44	N.E.	1·523			
			Mag. S.	24 06·6	44	N.E.				
4.	−54 48	297 21	Def. N.	42 33·1	44	N.E.	1·443			
			Def. S.	40 06·6	44	N.E.	1·428			
			Mag. N.	35 00·8	44	N.E.	1·420			
			Mag. N.S.	45 01·4	44	N.E.	1·440			
			Mag. S.	25 06·5	44	N.E.				
5.	−52 40	299 52	Def. N.	44 47·8	44	N.N.E.	1·325	+·025	1·355	Ship steady.
			Def. S.	42 29·0	44	N.N.E.	1·307			
			Mag. N.	36 03·2	44	N.N.E.	1·326			
			Mag. N.S.	46 17·6	44	N.N.E.	1·326			
			Mag. S.	25 40·2	44	N.N.E.				
			wt. 1 gr.	17 23·4	44	N.N.E.	1·284			
			wt. 1½ gr.	26 11·2	44	N.N.E.	1·304			

Observations of the Magnetic Force. (Continued.)

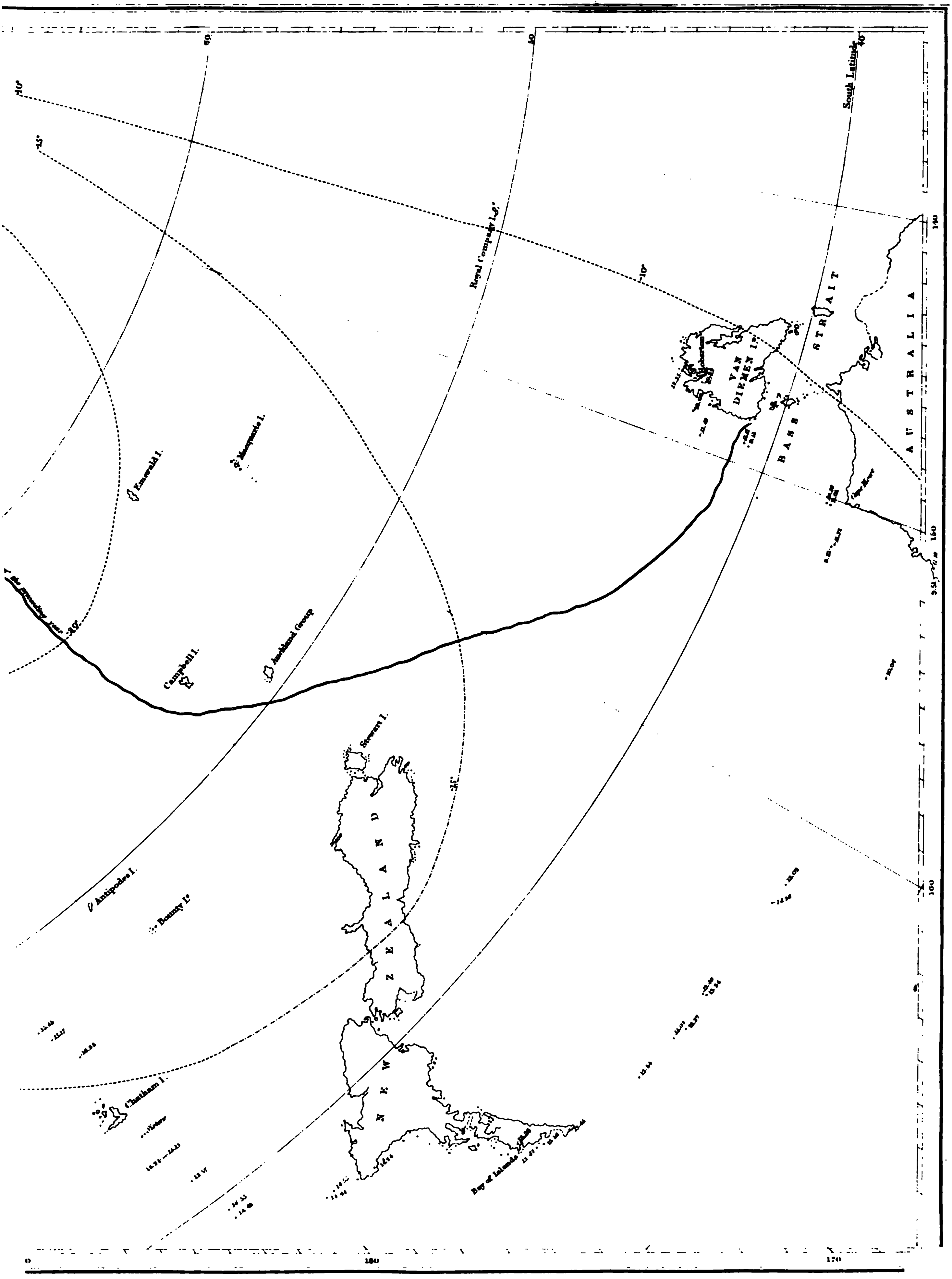
1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Tempera-ture.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
Apr. 5.	−52° 40′	299° 52′	wt. 2 grs.	34° 54′·7	44°	N.N.E.	1·351	+·025	1·355	Ship steady.
			wt. 2½ grs.	45 13·0	44	N.N.E.	1·344			
			wt. 3 grs.	54 16·9	44	N.N.E.	1·408			
	−52 28	301 42	Def. N.	44 40·6	44	N.N.E.	1·327	+·025		Ship steady.
			Def. S.	42 04·5	44	N.N.E.	1·326		1·340	
			Mag. N.	36 12·5	44	N.N.E.	1·313			
			Mag. N.S.	46 43·3	44	N.N.E.	1·290			
			Mag. S.	25 58·0	44	N.N.E.				
6.	−51 42	301 36	Def. N.	44 52·9	44	N.N.W. ½ W.	1·319	+·024		Slight motion.
			Def. S.	42 26·1	44	N.N.W. ½ W.	1·308			
			Mag. N.	36 14·5	44	N.N.W. ½ W.	1·309			
			Mag. N.S.	46 16·5	44	N.N.W. ½ W.	1·332			
			Mag. S.	26 08·0	44	N.N.W. ½ W.				
9.	Falkland Islands.		Def. N.	44 21·2	44	W. ½ N.	1·346	+·009	1·346	Single anchor in Port Louis, Berkeley Sound.
			Def. S.	42 02·4	44	W. ½ N.	1·328			
10.			Def. N.	44 58·5	43	Observed on shore.	1·314			At the Magnetic Station.
	−51 32	301 53	Def. S.	41 52·8	43		1·335			
			Mag. N.	35 57·0	43		1·336			
			Mag. N.S.	46 13·9	43		1·335			
			Mag. S.	25 37·0*	43					
			wt. 1 gr.	16 56·5	43		1·316		Mean of all the results obtained with weights at Port Louis 1·336.	
			wt. 1½ gr.	25 36·6	43		1·331			
			wt. 2 grs.	34 47·2	43		1·356			
			wt. 2½ grs.	45 34·1	43		1·336			
July 25.			wt. 3 grs.	57 39·1	43		1·353			
			Def. N.	44 27·0	43		1·340			
			Def. S.	42 00·4	43		1·330			
			Mag. N.	36 00·0	43		1·331			
			Mag. N.S.	46 13·2	43		1·336			
			Mag. S.	25 42·8	43					
			wt. 1 gr.	16 51·2	43		1·323			
			wt. 1½ gr.	25 34·3	43		1·333			
			wt. 2 grs.	34 47·8	43		1·355			
			wt. 2½ grs.	45 29·7	43		1·338			
			wt. 3 grs.	57 48·7†	43		1·350			
Aug. 15.			Def. N.	44 29·0	38		1·339			
			Def. S.	41 58·0	38		1·332			
			Mag. N.	36 00·9	38		1·330			
			Mag. N.S.	46 14·8	38		1·333			

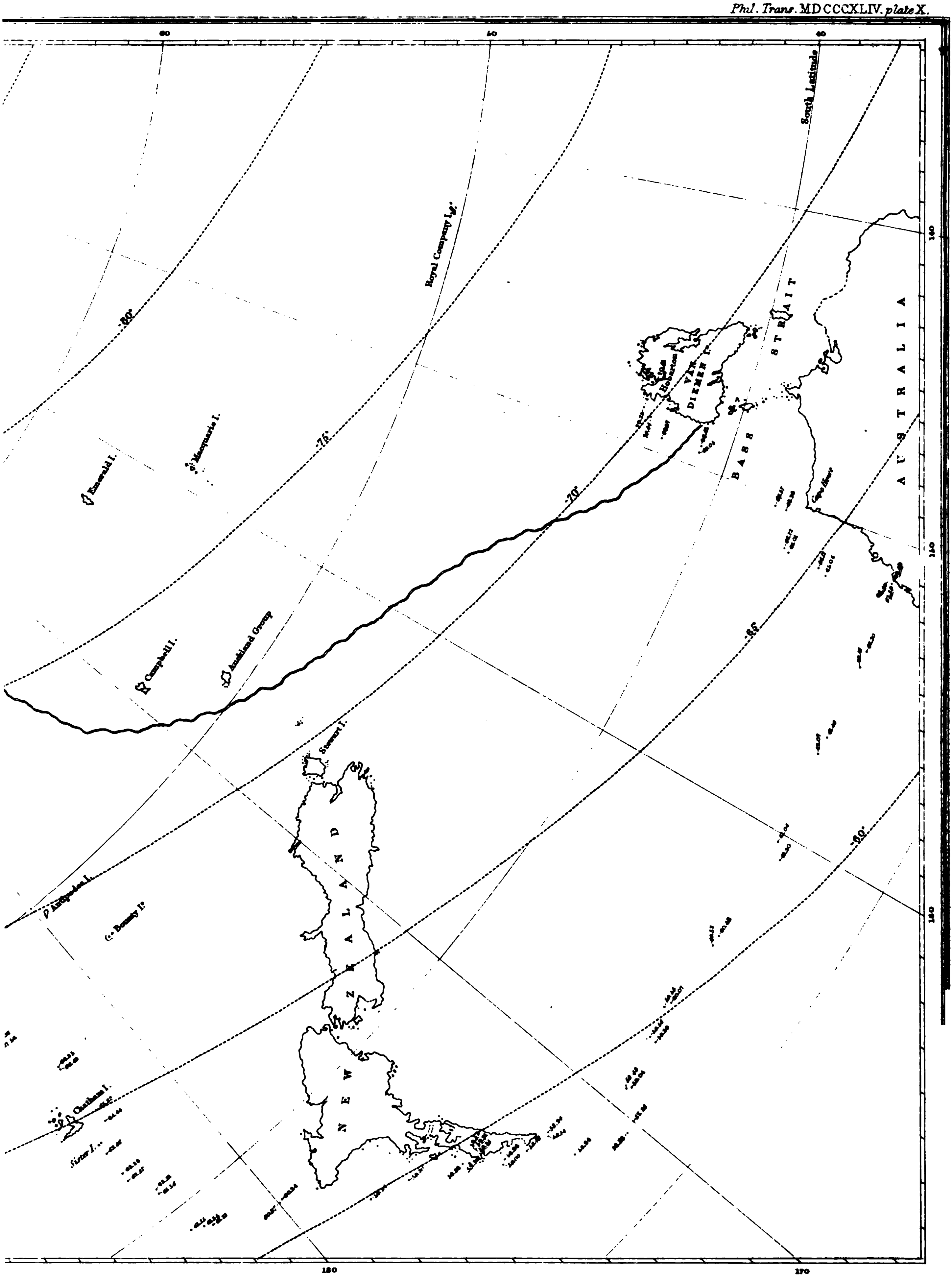
			Intensity.
* Observed on shore; face west.	wt. 1 gr.	16° 14′·1	1·316
	wt. 1½ gr.	24 36·9	1·338
	wt. 2 grs.	33 44·9	1·342
	wt. 2½ grs.	44 31·3	1·334
	wt. 3 grs.	58 17·8	1·333
† Observed on shore; face west.	wt. 1 gr.	16 26·1	1·301
	wt. 1½ gr.	24 27·9	1·345
	wt. 2 grs.	33 49·5	1·339
	wt. 2½ grs.	44 17·1	1·339
	wt. 3 grs.	58 19·5	1·333

Observations of the Magnetic Force. (Continued.)

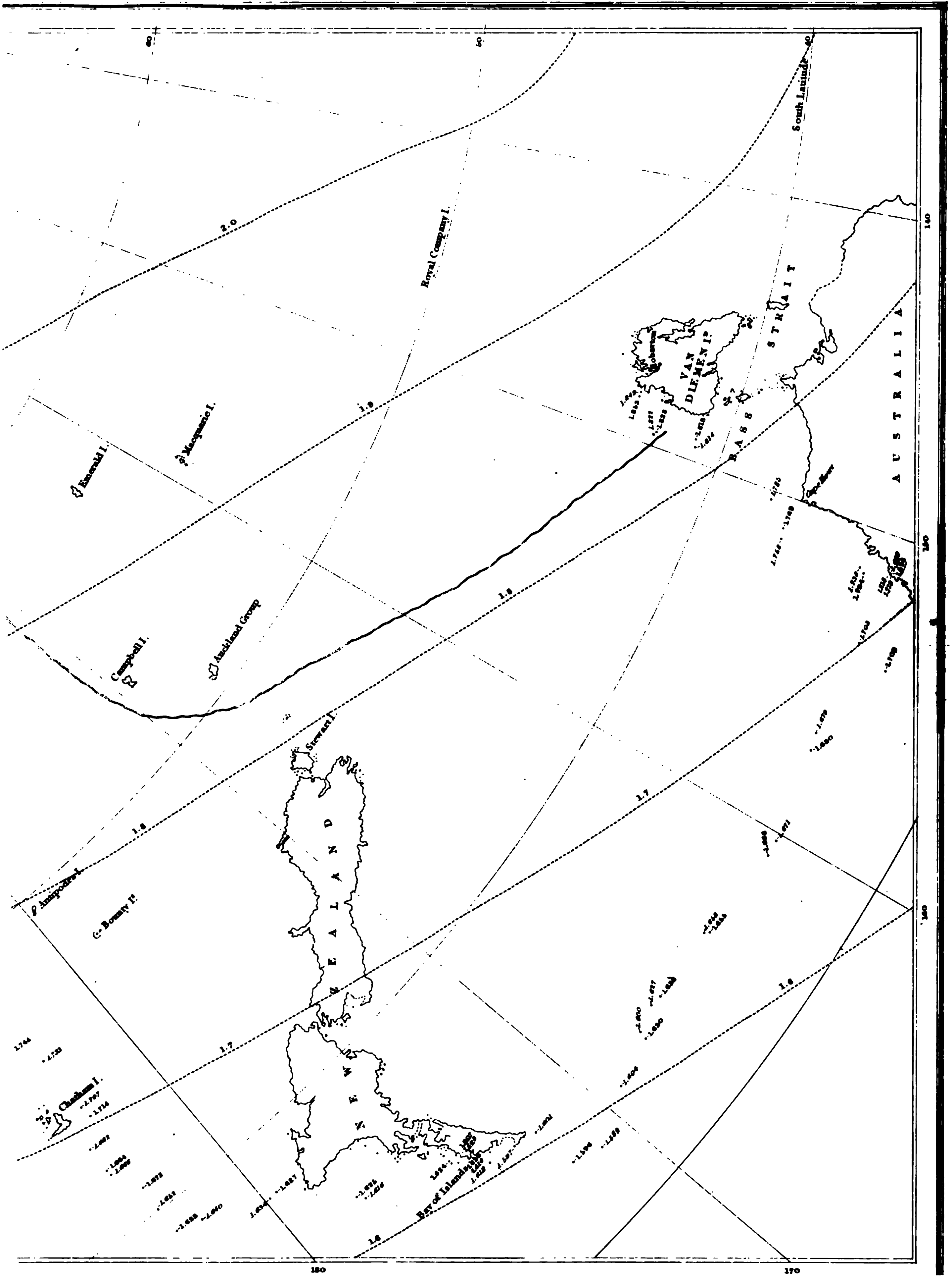
1842.	Lat.	Long.	Method employed.	Angle of deflection. Face east.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
	° ′	° ′		° ′	°					
Aug. 15.			Mag. S.	25 52·1*	38	Observed on shore.			Mean of all the results obtained with weights at Port Louis 1·336.	At the Magnetic Station.
			wt. 1 gr.	17 00·4	38		1·311			
			wt. 1½ gr.	25 37·3	38		1·331			
			wt. 2 grs.	34 24·4	38		1·369			
			wt. 2½ grs.	45 20·1	38		1·341			
			wt. 3 grs.	57 43·6	38		1·352			
18.			Def. N.	44 27·0	38		1·340			
			Def. S.	41 59·6	38		1·330			
			Mag. N.	35 59·3	38		1·332			
			Mag. N.S.	46 12·2	38		1·338			
			Mag. S.	25 43·8	38					
Aug. 15.	At anchor in Berkeley Sound.	To obtain corrections for the ship's attraction.	Def. N.	44 59·4	40	E. ½ S.	1·313	+·007	1·320	1·342
			Def. N.	44 32·3	40	E.	1·336	+·009	1·345	
			Def. N.	44 10·0	40	E.S.E.	1·355	—·003	1·352	
			Def. N.	43 52·8	40	S.E.	1·370	—·014	1·356	
			Def. N.	43 55·3	40	S.S.E.	1·368	—·023	1·345	
			Def. N.	43 52·3	40	S.	1·370	—·024	1·346	
			Def. N.	43 57·8	40	S.S.W.	1·366	—·023	1·343	
			Def. N.	44 05·9	40	S.W.	1·359	—·014	1·345	
			Def. N.	44 22·3	40	W.S.W.	1·345	—·003	1·342	
			Def. N.	44 47·5	40	W.	1·324	+·009	1·333	
			Def. N.	45 06·1	40	W.N.W.	1·308	+·017	1·325	
			Def. N.	45 01·7	40	N.W.	1·312	+·023	1·335	
			Def. N.	44 59·7	40	N.N.W.	1·313	+·025	1·338	
			Def. N.	44 52·2	40	N.	1·320	+·026	1·346	
			Def. N.	44 57·2	40	N.N.E.	1·315	+·025	1·340	
			Def. N.	44 59·0	40	N.E.	1·314	+·023	1·337	
			Def. N.	44 32·5	40	E.N.E.	1·336	+·017	1·353	

		° ′	Intensity.
* Observed on shore; face west.	wt. 1 gr.	16 15·4	1·315
	wt. 1½ gr.	24 30·1	1·344
	wt. 2 grs.	33 57·8	1·335
	wt. 2½ grs.	44 32·3	1·333
	wt. 3 grs.	57 35·7	1·344


South Latitude
60
50
40
140
150
160
170
180
Royal Company I.
Emerald I.
St Macquarie I.
Campbell I.
Auckland Group
Stewart I.
Antipodes I.
Bounty Is
Chatham I.
Bay of Islands
VAN DIEMEN Id
BASS STRAIT
AUSTRALIA
NEW ZEALAND



J.&C.Walker Sculpt.


60
50
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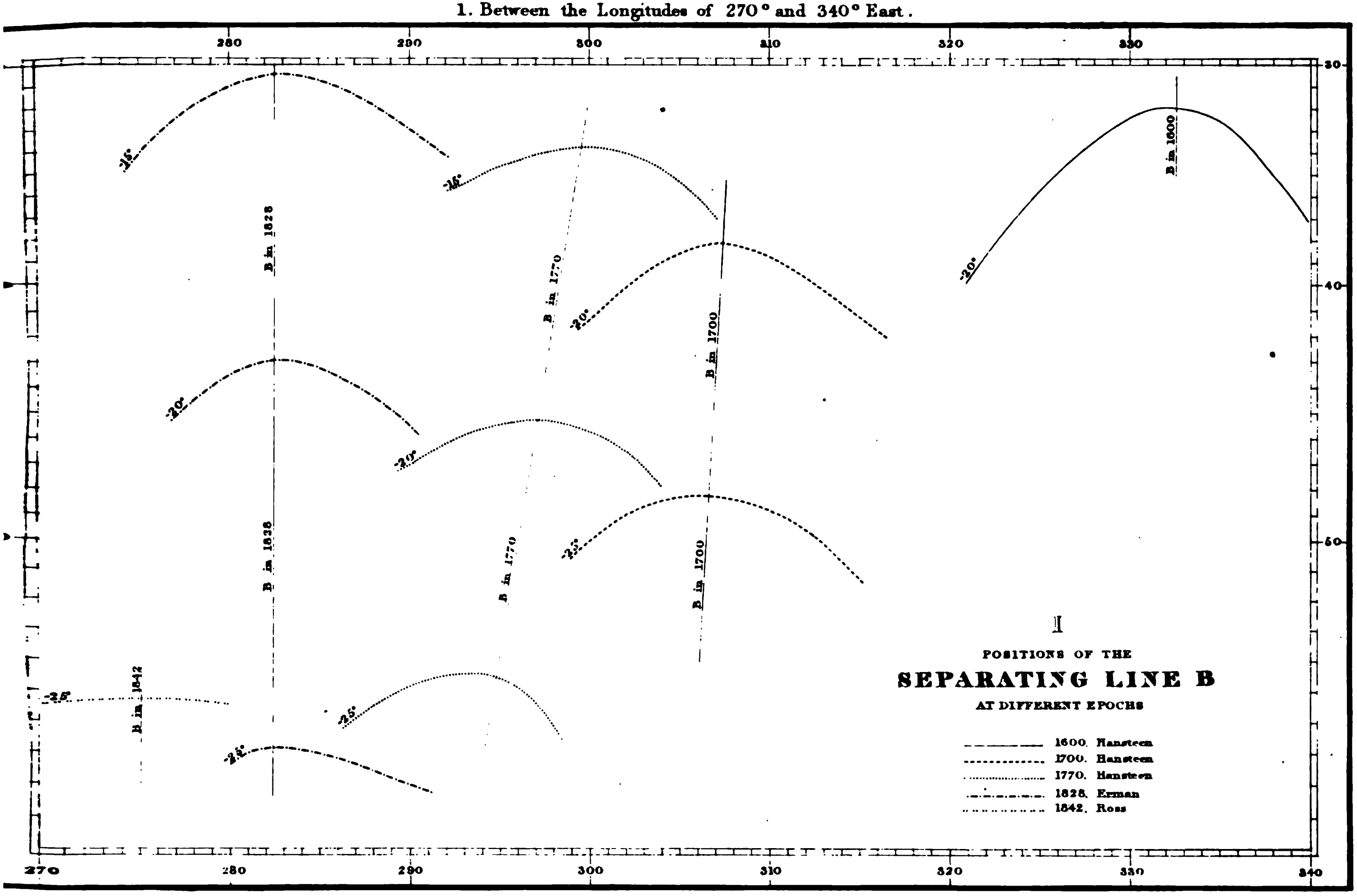
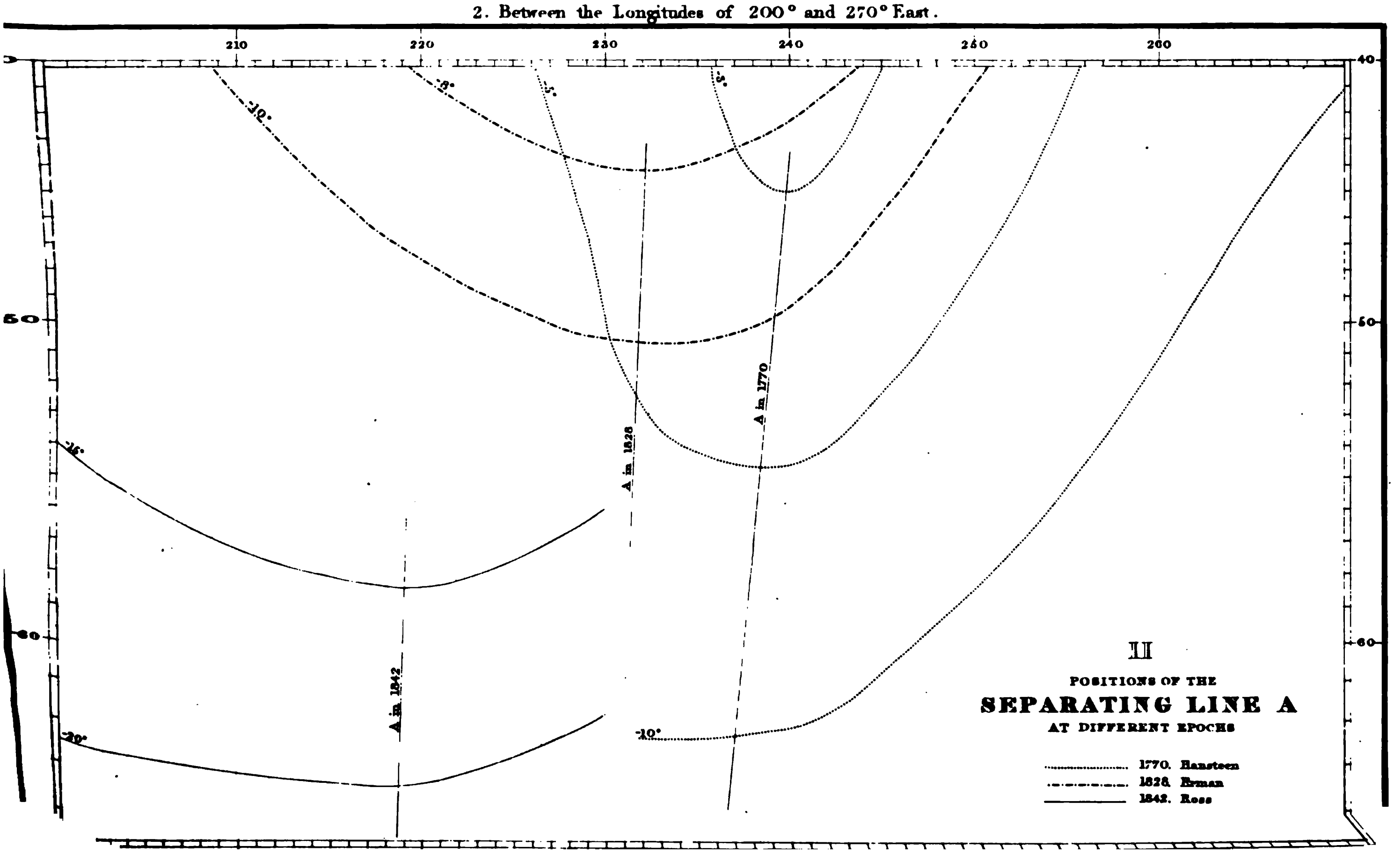
South Launde
Royal Company I.
2.0
1.9
1.8
1.7
1.6
VAN DIEMEN Iᴰ
BASS STRAIT
AUSTRALIA
Cape Howe
Sᵗ Macquarie I.
Emerald I.
Campbell I.
Auckland Group
Stewart I.
NEW ZEALAND
Antipodes I.
Bounty Iˢ
Chatham I.
Bay of Islands
140
150
160
170
180

Plate, shewing the progressive westerly movement of the Magnetic Phenomena in the
Southern Pacific Ocean.

1. Between the Longitudes of 270° and 340° East.



2. Between the Longitudes of 200° and 270° East.

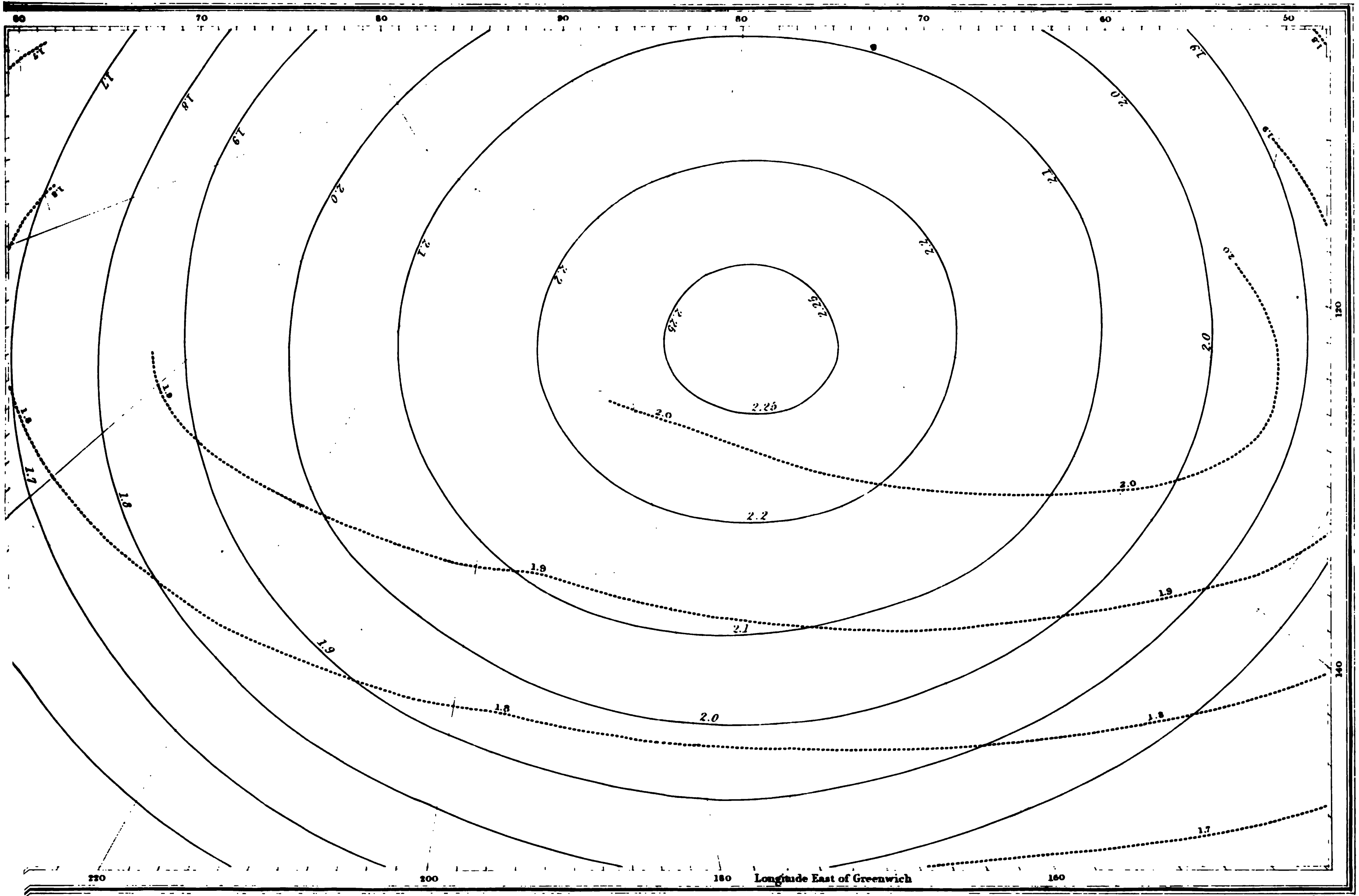


ENSITY DEDUCED FROM THE OBSERVATIONS OF

ION IN COMPARISON WITH M. GAUSS'S THEORETICAL LINES.

——— *M. Gauss's theoretical Lines*

······ *Lines deduced from the Observations of the Antarctic Expedition*



Engraved by J. & C. Walker.

VIII. *On a General Method in Analysis. By* GEORGE BOOLE, *Esq. Communicated by* S. HUNTER CHRISTIE, *Esq., Sec. R.S. &c.*

Received January 12th,—Read January 18th.

MUCH attention has of late been paid to a method in analysis known as the calculus of operations, or as the method of the separation of symbols. Mr. GREGORY, in his Examples of the Differential and Integral Calculus, and in various papers published in the Cambridge Mathematical Journal, vols. i. and ii., has both clearly stated the principles on which the method is founded, and shown its utility by many ingenious and valuable applications. The names of M. SERVOIS (Annales des Mathématiques, vol. v. p. 93), Mr. R. MURPHY (Philosophical Transactions for 1837), Professor DE MORGAN, &c., should also be noticed in connection with the history of this branch of analysis. As I shall assume for granted the principles of the method, and shall have occasion to refer to various theorems established by their aid, it may be proper to make some general remarks on the subject by way of introduction.

Mr. GREGORY lays down the fundamental principle of the method in these words: "There are a number of theorems in ordinary algebra, which, though apparently proved to be true only for symbols representing numbers, admit of a much more extended application. Such theorems depend only on the laws of combination to which the symbols are subject, and are therefore true for all symbols, whatever their nature may be, which are subject to the same laws of combination." The laws of combination which have hitherto been recognised are the following, π and ϱ being symbols of operation, u and v subjects.

1. The commutative law, whose expression is

$$\pi\varrho u=\varrho\pi u.$$

2. The distributive law,

$$\pi(u+v)=\pi u+\pi v.$$

3. The index law,

$$\pi^m\pi^n u=\pi^{m+n}u.$$

Perhaps it might be worth while to consider whether the third law does not rather express a necessity of notation, arising from the use of general indices, than any property of the symbol π.

The above laws are obviously satisfied when π and ϱ are symbols of quantity. They are also satisfied when π and ϱ represent such symbols as $\frac{d}{dx}$, Δ, &c., in combination with each other, or with *constant* quantities. Thus,

$$\frac{d}{dx}(au)=a\frac{du}{dx},$$

$$\frac{d}{dx}(u+v)=\frac{du}{dx}+\frac{dv}{dx}.$$

These properties of the symbol $\frac{d}{dx}$, taken in connection with the principle above enunciated, lead to the most important results that have been yet established by the calculus of operations. We have an early example of their application in the symbolical form of TAYLOR'S theorem, viz.

$$f(x+h)=\epsilon^{h\frac{d}{dx}}f(x).$$

A result to which we shall often refer is the following. If we have a linear equation with constant coefficients of the form

$$\pi^n u+A_1\pi^{n-1}u+A_2\pi^{n-2}u\ldots+A_n u=X,$$

wherein π operates solely on u, and is therefore *commutative* with respect to A_1, A_2, &c., then

$$u=\{\pi^n+A_1\pi^{n-1}+A_2\pi^{n-2}\,..+A_n\}^{-1}X$$
$$=N_1(\pi-a_1)^{-1}X+N_2(\pi-a_2)^{-1}X+\text{ \&c.},$$

N_1, $N_2\,..\,a_1$, $a_2\,..$ having the same values as in the resolution of the rational fraction $\frac{1}{\xi^n+A_1\xi^{n-1}\,..\,+A_n}$ into a similar series of terms*.

It is obvious that the above method is of necessity limited in its application. It is only in linear equations with *constant* coefficients that the operative symbols combine in subjection to the law we have supposed. Accordingly it has been remarked, that the calculus of operations has tended rather to simplify the processes of analysis than to extend its power.

The object of this paper is to develope a method in analysis, which, while it operates with symbols apart from their subjects, and may thus be considered as a branch of the calculus of operations, is nevertheless free from the restrictions to which we have alluded. The linear equation with variable coefficients, whether in differentials or in finite differences, will be treated under the form

$$f_0(\pi)u+f_1(\pi)\rho u+f_2(\pi)\rho^2u+\text{ \&c.}=U,$$

U being a function of the independent variable x, and π and ρ operative symbols, which combine in subjection to the law

$$f(\pi)\rho^m u=\rho^m f(\pi+m)u,$$

and which, when the subject function u is unity, further satisfy the relation

$$f(\pi)\rho^m=f(m)\rho^m.$$

It might be expected, *à priori*, that a theory of linear equations founded on such a basis, would be of peculiar character. Its actual advantages I conceive to be the following:—

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* Cambridge Mathematical Journal, vol. ii. p. 114, vol. iii. p. 239.

1. The necessary reductions, transformations and developments are effected, for the most part, by theorems, the expression of which is independent of the forms of $f_0(\pi)$, $f_1(\pi)$, &c.

2. We are thus able to establish a perfectly general method for the solution of linear differential equations total and partial in series, and for the calculus of generating functions.

3. The form of the analysis affords facilities, which are believed to be peculiar to itself, for the finite integration of linear equations, and for the classification of integrable forms.

The received theory of the solution of linear differential equations in series is given by EULER[*]. It consists in assuming $u=\Sigma a_m x^m$, and determining by substitution the relation connecting the successive values of a_m, or as it is called, the scale of the equation. This method fails when, in seeking the first index of a development, we arrive at equal or imaginary values. I am not aware that any mathematician has shown how this failure is to be remedied. Now the method developed in this paper has no such cases of exception.

The theory of series and of generating functions has been successively discussed by EULER and LAPLACE. A full account of their researches is given in LACROIX's larger treatise on the Calculus, tom. iii., in the chapters *Théorie des Suites* and *Théorie des Fonctions Génératrices*. I class these investigations together, because, although their objects are distinct, their mathematical theories are virtually the same. EULER proposes to determine the generating function of a series, $\Sigma u_m t^m$, when the coefficients are formed according to such a law as the following:

$$u_m=\frac{(am+b)(a_1m+b_1)\ldots}{(cm+e)(c_1m+e_1)\ldots}u_{m-1}.$$

He shows that by successive differentiations and integrations, the factors $am+b$, $cm+e\ldots$ may be eliminated, and the problem finally reduced to the solution of a differential equation. LAPLACE[†], considering the unknown quantity u_x in an equation of differences as the general coefficient of the expansion of a function u, proposes to determine u, and then by expansion to obtain u_x. It is not necessary for us to consider here whether the theory of generating functions is of any importance to the solution of equations of differences. The discovery of the generating function of a series is in itself a problem both interesting and important. Those who have paid attention to the subject will, I think, admit that the theories by which EULER and LAPLACE have endeavoured to accomplish this object, labour under two defects, one arising from the tedious character of the process by which the differential equation is formed, the other from the difficulty of its integration. This does by no means derogate from the genius or the claims of those wonderful men;

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[*] Calc. Integ. vol. ii.

[†] Théorie des Probabilités.

for the value of every discovery is in some measure relative, and is to be measured by the state of contemporary science as well as by its abstract merit.

The advantages which the method of this paper is believed to possess as respects the theory of series, are the following:—

1. The law of the series being known, or the equation of differences given, the differential equation is known by inspection. The rule is absolutely general, whatever may be the forms of the coefficients.

2. The form under which the differential equation is presented offers great facilities for its integration. Those facilities are chiefly owing to the circumstance, that the form of the equation permits us, as before remarked, to effect the requisite transformations by general theorems. That this form has a peculiar fitness for the processes of integration, is further shown by the circumstance, that the method of resolution which in the common theory leads to the solution of differential equations with constant coefficients, conducts us here to the solution of a large class of equations with variable coefficients.

The arrangement of the subjects treated in this paper will lead us to consider,—1st, linear differential equations; 2nd, the theory of series; 3rd, the theory of generating functions; 4th, the theory of equations of finite differences.

A. *Preliminary Theorems.*

Prop. 1. Let π and ϱ be distributive symbols which combine in subjection to the law

$$\varrho f(\pi)u=\lambda f(\pi)\varrho u, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

λ being a functional symbol operating on π, in such manner that $\lambda f(\pi)=f(\varphi(\pi))$, it is required to expand $f(\pi+\varrho)$ in ascending powers of ϱ.

We have

$$\left.\begin{array}{l} \varrho f(\pi)u=\lambda f(\pi)\varrho u, \\ \varrho^2 f(\pi)u=\lambda^2 f(\pi)\varrho^2 u, \\ \quad . \quad . \quad . \quad . \quad . \quad . \quad . \\ \varrho^m (f\pi)u=\lambda^m f(\pi)\varrho^m u \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.)$$

Let $\pi+\varrho=\eta$, then $f(\pi+\varrho)u=f(\eta)u$. Now, as η operates solely on u, it is *commutative* with respect to the constants in $f(\eta)$, wherefore

$$\eta f(\eta)u=f(\eta)\eta u.$$

Or dropping the subject u, and writing $\pi+\varrho$ for η,

$$(\pi+\varrho)f(\pi+\varrho)=f(\pi+\varrho)(\pi+\varrho).$$

Let $f(\pi+\varrho)u=\Sigma f_m(\pi)\varrho^m u$, then, still supposing u to be understood,

$$\begin{aligned} (\pi+\varrho)f(\pi+\varrho) &= \pi\Sigma f_m(\pi)\varrho^m+\varrho\Sigma f_m(\pi)\varrho^m, \\ &= \Sigma\pi f_m(\pi)\varrho^m+\Sigma\varrho f_m(\pi)\varrho^m, \\ &= \Sigma\pi f_m(\pi)\varrho^m+\Sigma\lambda f_m(\pi)\varrho^{m+1} \text{ by (2).} \end{aligned}$$

Under the first Σ in the second member the coefficient of ρ^m is $\pi f_m(\pi)$, and under the second Σ the coefficient of ρ^m is $\lambda f_{m-1}(\pi)$, wherefore the aggregate coefficient of ρ^m in the expansion of $(\pi+\rho)f(\pi+\rho)$ is

$$\pi f_m(\pi)+\lambda f_{m-1}(\pi). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.)$$

Again, we have

$$\begin{aligned} f(\pi+\rho)(\pi+\rho) &= \Sigma f_m(\pi)\rho^m(\pi+\rho), \\ &= \Sigma f_m(\pi)\rho^m\pi+\Sigma f_m(\pi)\rho^{m+1}, \\ &= \Sigma f_m(\pi)\lambda^m\pi\rho^m+\Sigma f_m(\pi)\rho^{m+1} \text{ by (2.),} \end{aligned}$$

wherein the aggregate coefficient of ρ^m is

$$f_m(\pi)\lambda^m\pi+f_{m-1}(\pi).$$

Equating this expression with (3.), we have

$$f_m(\pi)\lambda^m\pi+f_{m-1}(\pi)=\pi f_m(\pi)+\lambda f_{m-1}(\pi);$$

$$\therefore \qquad f_m(\pi)=\frac{\lambda f_{m-1}(\pi)-f_{m-1}(\pi)}{\lambda^m\pi-\pi};$$

or separating the symbols,

$$f_m(\pi)=\frac{(\lambda-1)f_{m-1}(\pi)}{(\lambda^m-1)\pi}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.)$$

which expresses the law of formation of the coefficients.

The first term $f_0(\pi)$ is equal to $f(\pi)$: this may be proved by induction from the particular cases of $(\pi+\rho)^2$, $(\pi+\rho)^3$, &c., but perhaps more rigidly thus. Let k be a symbol such that $kf(\pi)=f_0(\pi)$. Then the first term of the expansion of $(\pi+\rho)f(\pi+\rho)$ is $k\pi f(\pi)$; but by (3.) this term is $\pi f_0(\pi)=\pi kf(\pi)$, therefore

$$k\pi f(\pi)=\pi kf(\pi);$$

wherefore π and k are *commutative*. It is hence evident that k can only operate as a constant multiplier, the value of which is independent of the form of $f(\pi)$. Let $f(\pi)=\pi$, then, since $f(\pi+\rho)=\pi+\rho$, it is evident that $k=1$, wherefore

$$f_0(\pi)=f(\pi),$$

and the expansion is completely determined.

Cor. If the symbols π and ρ combine according to the law

$$\rho f(\pi)u=f(\pi+\Delta\pi)\rho u,$$

$\Delta\pi$ being any constant increment, then

$$f(\pi+\rho)=f(\pi)+\frac{\Delta}{\Delta\pi}f(\pi)\rho+\frac{\Delta^2}{\Delta\pi^2}f(\pi)\frac{\rho^2}{1.2}+\frac{\Delta^3}{\Delta\pi^3}f(\pi)\frac{\rho^3}{1.2.3}, \quad . \quad . \quad . \quad . \quad (I.)$$

the interpretation of $\frac{\Delta}{\Delta\pi}$ being

$$\frac{\Delta}{\Delta\pi}f(\pi)=\frac{f(\pi+\Delta\pi)-f(\pi)}{\Delta\pi};$$

For $\lambda f(\pi)=f(\pi+\Delta\pi)$. Hence $\lambda^m\pi=\pi+m\Delta\pi$ and (4.) gives

$$f_m(\varpi)=\frac{f_{m-1}(\varpi+\Delta\varpi)-f_{m-1}(\varpi)}{m\Delta\varpi}$$
$$=\frac{1}{m}\frac{\Delta}{\Delta\varpi}f_{m-1}(\varpi),$$

whence the theorem is manifest.

If $\Delta\varpi=-1$, we find

$$f(\varpi+\varrho)=f_0(\varpi)+f_1(\varpi)\varrho+\frac{1}{1.2}f_2(\varpi)\varrho^2+\text{ \&c.},$$

where $f_0(\varpi)=f(\varpi)$, and in general $f_m(\varpi)=f_{m-1}(\varpi)-f_{m-1}(\varpi-1)$.

If $\Delta\varpi$ vanishes the symbols ϖ and ϱ are commutative, $\frac{\Delta}{\Delta\varpi}$ becomes $\frac{d}{d\varpi}$, and (I.) is reduced to Taylor's theorem.

Prop. 2. If $\varrho=\varphi(x)\epsilon^{r\frac{d}{dx}}$ then x and ϱ combine according to the law

$$\varrho f(x)u=f(x+r)\varrho u.$$

For writing u_x in the place of u, we have

$$\varrho f(x)u_x=\varphi(x)\epsilon^{r\frac{d}{dx}}f(x)u_x,$$
$$=\varphi(x)f(x+r)u_{x+r},$$
$$=f(x+r)\varphi(x)\epsilon^{r\frac{d}{dx}}u_x,$$
$$=f(x+r)\varrho u.$$

Prop. 3. If $\varpi=\frac{n\phi(x)\epsilon^{r\frac{d}{dx}}-x}{r}$ and $\varrho=\varphi(x)\epsilon^{r\frac{d}{dx}}$, then ϖ and ϱ combine according to the law

$$\varrho f(\varpi)u=f(\varpi-1)\varrho u,$$

we have $f(\varpi)=f\left(\frac{n\varrho-x}{r}\right)$. Now ϱ combines with x according to the law

$$\varrho f(x)u=f(x+r)\varrho u, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5.)$$

and ϱ combines with ϱ as if it were a mere symbol of quantity; hence

$$\varrho f\left(\frac{n\varrho-x}{r}\right)u=f\left(\frac{n\varrho-(x+r)}{r}\right)\varrho u \text{ by Prop. 2,}$$
$$=f\left(\frac{n\varrho-x}{r}-1\right)\varrho u,$$
$$=f(\varpi-1)\varrho u.$$

This result may also be proved by expanding $f\left(\frac{n\varrho-x}{r}\right)$ in ascending powers of ϱ by Prop. 1, and operating with ϱ on each term of the series.

Prop. 4. If $\varpi=\frac{x\epsilon^{r\frac{d}{dx}}-x}{r}$ and $\varrho=x\epsilon^{r\frac{d}{dx}}$, then ϖ and ϱ satisfy the following relations,

$$f(\pi)\varrho^m u=\varrho^m f(\pi+m)u, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(II.)}$$

$$f(\pi)\varrho^m \;=f(m)\varrho^m, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(III.)}$$

the subject u becoming unity in the second of the above equations.

For in the last Prop. let $\varphi(x)=x$, and $n=1$, then $\pi=\frac{x\varepsilon^{r\frac{d}{dx}}-x}{r}$, $\varrho=x\varepsilon^{r\frac{d}{dx}}$, and

$$\varrho f(\pi)u=f(\pi-1)\varrho u.$$

By induction, $\varrho^m f(\pi)u=f(\pi-m)\varrho^m u$;

$$\therefore \qquad f(\pi)\varrho^m u=\varrho^m f(\pi+m)u,$$

which is the first of the proposed relations. Now m being a constant is *commutative* with π, wherefore expanding $f(\pi+m)$ in the second member by TAYLOR's theorem, in ascending powers of π, we have

$$f(\pi)\varrho^m u=\varrho^m\{f(m)u+f'(m)\pi u+f''(m)\frac{\pi^2}{1.2}u+\&\text{c.}\}.$$

For u write u_x, then

$$\pi u_x=\frac{x\varepsilon^{r\frac{d}{dx}}-x}{r}u_x,$$

$$=\frac{xu_{x+r}-xu_x}{r},$$

which vanishes if $u_x=1$. In like manner π^2u_x, π^3u_x, &c. vanish under similar circumstances, wherefore

$$f(\pi)\varrho^m(1)=\varrho^m f(m)(1),$$

$$f(\pi)\varrho^m=f(m)\varrho^m,$$

which is the second of the relations in question.

Prop. 5. The same values being attributed to π and ϱ, we shall have

$$\pi(\pi-1)..(\pi-n+1)u=x(x+r)..(x+(n-1)r)\left(\frac{\Delta}{\Delta x}\right)^n u, \quad . \quad . \quad . \quad \text{(IV.)}$$

wherein $\Delta x=r$.

We have $\qquad \pi=\frac{\rho-x}{r},$

$$\therefore \qquad \varrho^{-1}\pi u=\frac{1-\rho^{-1}x}{r}u.$$

Now $\qquad \varrho^{-1}xu=\left(x\varepsilon^{r\frac{d}{dx}}\right)^{-1}xu=\varepsilon^{-r\frac{d}{dx}}\,x^{-1}xu=\varepsilon^{-r\frac{d}{dx}}u,$

therefore $\qquad \varrho^{-1}\pi u=\frac{1-\varepsilon^{-r\frac{d}{dx}}}{r}u,$

$$\therefore \qquad (\varrho^{-1}\pi)^n u=\left\{\frac{1-\varepsilon^{-r\frac{d}{dx}}}{r}\right\}^n u.$$

Now $\qquad (\varrho^{-1}\pi)^2u=\varrho^{-1}\pi\varrho^{-1}\pi u=\varrho^{-2}(\pi-1)\pi u=\varrho^{-2}\pi(\pi-1)u,$

and by induction, $$(\rho^{-1}\pi)^n u=\rho^{-n}\pi(\pi-1)..(\pi-n+1)u,$$

$$\therefore \qquad \rho^{-n}\pi(\pi-1)..(\pi-n+1)u=\left\{\frac{1-\epsilon^{-r\frac{d}{dx}}}{r}\right\}^n u,$$

whence $$\pi(\pi-1)..(\pi-n+1)u=\rho^n\left\{\frac{1-\epsilon^{-r\frac{d}{dx}}}{r}\right\}^n u.$$

But $$\rho^n=x(x+r)..(x+(n-1)r)\epsilon^{nr\frac{d}{dx}},$$

wherefore $$\pi(\pi-1)..(\pi-n+1)u=x(x+r)..(x+(n-1)r)\left\{\frac{\epsilon^{r\frac{d}{dx}}-1}{r}\right\}^n u,$$

$$=x(x+r)..(x+(n-1)r)\left(\frac{\Delta}{\Delta x}\right)^n u.$$

Scholium. In the values of π and ρ employed in the two last propositions, if we expand the exponential $\epsilon^{r\frac{d}{dx}}$, we find

$$\pi=x\left(\frac{d}{dx}+\frac{1}{1.2}r\frac{d^2}{dx^2}+\frac{1}{1.2.3}r^2\frac{d^3}{dx^3}+\&c.\right),$$

$$\rho=x\left(1+r\frac{d}{dx}+\frac{r^2}{1.2}\frac{d^2}{dx^2}+\&c.\right).$$

Let $r=0$, then $\pi=x\frac{d}{dx}$, $\rho=x$. Put $x=\epsilon^\theta$, then $\pi=\frac{d}{d\theta}$, $\rho=\epsilon^\theta$. For simplicity, let us represent $\frac{d}{d\theta}$ by D, then by (II.), (III.), (IV.) the symbols D and ϵ^θ satisfy the following relations:

$$f(\mathrm{D})\epsilon^{m\theta}u=\epsilon^{m\theta}f(\mathrm{D}+m)u. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(V.)}$$

$$f(\mathrm{D})\epsilon^{m\theta}=f(m)\epsilon^{m\theta}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(VI.)}$$

$$\mathrm{D}(\mathrm{D}-1)..(\mathrm{D}-n+1)u=x^n\left(\frac{d}{dx}\right)^n u. \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(VII.)}$$

These are known relations. With a view to the maintenance of an unbroken analogy, it has, however, been thought better to deduce them from the properties of the more general system in π and ρ, than to assume them as already proved.

B. § 1. *Theory of Linear Differential Equations.*

Prop. 1. Every linear differential equation which can, with or without expansion of its coefficients, be placed in the form

$$(a+bx+cx^2..)\frac{d^nu}{dx^n}+(a'+b'x+c'x^2..)\frac{d^{n-1}u}{dx^{n-1}}+\&c.=\mathrm{X},$$

may be reduced to the *symbolical* form

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\epsilon^\theta u+f_2(\mathrm{D})\epsilon^{2\theta}u...=\mathrm{U}, \quad . \quad . \quad . \quad . \quad . \quad \text{(VIII.)}$$

wherein f_0, f_1, f_2... are functional symbols, and U is a function of ϵ^θ.

For multiplying by x^n, and considering first the expression $(a+bx+cx^2..)x^n\frac{d^nu}{dx^n}$, let $x=\varepsilon^{\theta}$, we have

$$\begin{aligned}&(a+b\varepsilon^{\theta}+c\varepsilon^{2\theta}..)\mathrm{D}(\mathrm{D}-1)..(\mathrm{D}-n+1)u,\\ &=a\mathrm{D}(\mathrm{D}-1)..(\mathrm{D}-n+1)u,\\ &\quad+b(\mathrm{D}-1)(\mathrm{D}-2)..(\mathrm{D}-n)\varepsilon^{\theta}u,\\ &\quad+c(\mathrm{D}-2)(\mathrm{D}-3)..(\mathrm{D}-n-1)\varepsilon^{2\theta}u.\\ &\quad\cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\end{aligned}$$

In like manner may every term in the first member of the original equation be reduced; also the second member, which is a function of x, will become a function of ε^{θ}; the aggregate of these results will produce an equation of the form (VIII.).

More generally, let it be supposed that we have a system of linear differential equations, total or partial, the dependent variables being $u_1v_1..$ the independent variables $x_1x_2..$ whereof the second members of the equations are functions; if we assume $x_1=\varepsilon^{\theta_1}$, $x_2=\varepsilon^{\theta_2}..$ the transformed equations may be so written as to satisfy the following conditions.

1st. Every term involving u shall be of the form $\phi(\mathrm{D}_1, \mathrm{D}_2..)\varepsilon^{r_1\theta_1+r_2\theta_2}u$, and similarly for every term involving v.

2nd. The second members shall be functions of ε^{θ_1}, $\varepsilon^{\theta_2}...$

Let us now consider the expression $f_0(\mathrm{D})u+f_1(\mathrm{D})\varepsilon^{\theta}u+f_2(\mathrm{D})\varepsilon^{2\theta}u..$, and let us therein assume $u=\Sigma u_m\varepsilon^{m\theta}$, then passing the symbols $f_0(\mathrm{D})$, $f_1(\mathrm{D})...$ within the sign of summation, collecting the coefficients of $\varepsilon^{m\theta}$, and observing that $f_0(\mathrm{D})\varepsilon^{m\theta}=f_0(m)\varepsilon^{m\theta}$, &c., we have

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\varepsilon^{\theta}u+f_2(\mathrm{D})\varepsilon^{2\theta}u...=\Sigma\{(f_0(m)u_m+f_1(m)u_{m-1}+f_2(m)u_{m-2}...)\varepsilon^{m\theta}\}\quad .\ \ .\ \ \text{(IX.)}$$

which is a particular form of the *fundamental theorem of development*.

To any aggregate of terms of the form $\phi(\mathrm{D}_1, \mathrm{D}_2..)\varepsilon^{r_1\theta_1+r_2\theta_2..}u$ the same analysis is applicable, whence our fundamental theorem, viz.

If $u=\Sigma u_{m,n...}\varepsilon^{m\theta_1+n\theta_2..}$,

then $$\phi(\mathrm{D}_1, \mathrm{D}_2..)\varepsilon^{r_1\theta_1+r_2\theta_2..}u=\Sigma\{\phi(m,n..)u_{m-r_1,\,n-r_2..}\varepsilon^{m\theta_1+n\theta_2}...\}.\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\quad \text{(X.)}$$

In applying this theorem to an expression consisting of many terms, the sign Σ must be affixed to the aggregate in the second member, as in (IX.), and not to each term separately.

The relation which the first member of (IX.) bears to the linear differential equation, is the same as is borne by the coefficient of $\varepsilon^{m\theta}$ in the second member to the linear equation of finite differences. This analogy extends to the fundamental theorem, which may be defined as a general relation connecting any linear differential equation, or system of linear differential equations, with a corresponding equation or system of equations in finite differences.

B. § 2. *On the Solution of Linear Differential Equations by Series.*

Since, when $u=\Sigma u_m \epsilon^{m\theta}$, we have

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\epsilon^{\theta}u+f_2(\mathrm{D})\epsilon^{2\theta}u\ldots=\Sigma\{(f_0(m)u_m+f_1(m)u_{m-1}+f_2(m)u_{m-2}\ldots)\epsilon^{m\theta}\},$$

it follows that the linear differential equation

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\epsilon^{\theta}u+f_2(\mathrm{D})\epsilon^{2\theta}u\ldots=0 \quad \ldots\ldots\ldots \quad (6.)$$

will be satisfied by the assumption $u=\Sigma u_m\epsilon^{m\theta}$, provided that

$$f_0(m)u_m+f_1(m)u_{m-1}+f_2(m)u_{m-2}\ldots=0. \quad \ldots\ldots \quad (7.)$$

Let p be the lowest value of m, then since u_{p-1}, u_{p-2}, &c. vanish, we have from (7.) $f_0(p)=0$, whence the values of p are determined. If p have n real values, there will be n ascending developments of the form

$$u=u_p\epsilon^{p\theta}+u_{p+1}\epsilon^{(p+1)\theta}+u_{p+2}\epsilon^{(p+2)\theta}\ldots \textit{ ad infinitum},$$

u_p in each development being arbitrary, and the succeeding coefficients formed according to the law (7.).

This method fails when p has equal or imaginary values, but the following rule is of universal application.

RULE.—*Solve the equation* $f_0(\mathrm{D})u=0$, *and let the complete integral be*

$$u=\mathrm{AP}+\mathrm{BQ}+\mathrm{CR}\ldots,$$

wherein A, B, C.. *are arbitrary constants, and* P, Q, R.. *functions of* θ. *Substitute this value of u in the original equation* (6.), *regarding* A, B, C.. *as variable parameters; the result will be of the form*

$$\mathrm{A'P}+\mathrm{B'Q}+\mathrm{C'R}\ldots=0, \quad \ldots\ldots\ldots \quad (\mathrm{XI.})$$

A′, B′, C′.., *being linear functions of* A, B, C.., *and their differential coefficients*; P, Q, R.., *as before. The system of equations*

$$\mathrm{A'}=0, \quad \mathrm{B'}=0, \quad \mathrm{C'}=0\ldots.$$

being then integrated by the fundamental theorem, the values of A, B, C *will be determined in the forms* $\mathrm{A}=\Sigma a_m\epsilon^{m\theta}$, $\mathrm{B}=\Sigma b_m\epsilon^{m\theta}$, &c., a_0 b_0.. *being arbitrary constants**.

The equation to be solved is

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\epsilon^{\theta}u\ldots+f_r(\mathrm{D})\epsilon^{r\theta}u=0,$$

in which $f_0(\mathrm{D})f_1(\mathrm{D})$, &c. are rational and integral combinations of D. This equation may be put under the form

$$\Sigma\{f_n(\mathrm{D})\epsilon^{n\theta}u\}=0, \quad \ldots\ldots\ldots\ldots \quad (8.)$$

the summation extending from $n=0$ to $n=r$.

Now the solution of the equation $f_0(\mathrm{D})u=0$ is of the form

$$u=\mathrm{AP}+\mathrm{BQ}+\mathrm{CR}+\&\mathrm{c}., \quad \ldots\ldots\ldots \quad (9.)$$

wherein A, B, C... are arbitrary constants, and P, Q, R... particular values of $\{f_0(\mathrm{D})\}^{-1}0$. Substituting this expression in (8.), and regarding A, B, C... as variable parameters, we have

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* The reader may find it advantageous to look over some of the examples in which this rule is applied before reading the demonstration.

$$\Sigma\{f_n(\mathrm{D})\varepsilon^{n\theta}(\mathrm{AP}+\mathrm{BQ}\ldots)\}=0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10.)$$

to determine the general character of which let us first consider the term $f_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{AP}$.

Separating the factors $\varepsilon^{n\theta}\mathrm{A}$ and P, if we expand the operative symbol $f_n(\mathrm{D})$, as in Leibnitz's theorem, we have

$$f_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{AP}=f_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{A}\times\mathrm{P}+f'_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{A}\times\mathrm{DP}+f''_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{A}\times\frac{1}{1.2}\mathrm{D}^2\mathrm{P}+\&c. \quad . \quad . \quad (10'.)$$

The general value of $\mathrm{D}^i\mathrm{P}$ may be thus ascertained:

$$\begin{aligned}(\mathrm{D})^i\mathrm{P}&=(\mathrm{D})^i\{f_0(\mathrm{D})\}^{-1}0,\\ &=\{f_0(\mathrm{D})\}^{-1}(\mathrm{D})^i0,\\ &=\{f_0(\mathrm{D})\}^{-1}0,\\ &=\mathrm{LP}+\mathrm{MQ}+\mathrm{NR}\ldots,\end{aligned}$$

L, M, N.. being arbitrary constants. In the present instance, as P does not involve any arbitrary constants, and as the direct operation $(\mathrm{D})^i$ cannot introduce any, it is evident that L, M, N are simply numerical coefficients.

The above expression for $(\mathrm{D})^i\mathrm{P}$ applying to every term of the second member of (10'.), it is obvious that $f_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{AP}$ will be a linear function of P, Q, R.., whose coefficients are of the general type $\phi_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{A}$, $\phi_n(\mathrm{D})$ denoting a rational and integral combination of (D). In like manner, $f_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{BQ}$ will be a linear function of P, Q, R, the coefficients whereof will assume the form $\psi_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{B}$. Wherefore the equation (10.) will become

$$\mathrm{A'P}+\mathrm{B'Q}+\mathrm{C'R}..=0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11.)$$

every coefficient A′, B′, &c. being of the type

$$\Sigma\{\phi_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{A}\}+\Sigma\{\psi_n(\mathrm{D})\varepsilon^{n\theta}\mathrm{B}\}+\&c.;$$

and it is to be remarked, that the terms in this expression which correspond to a particular value of n, are derived from the term which answers to the same value of n in the primitive equation (8.).

In order to satisfy (11.) independently of the particular values of P, Q, R, let us assume

$$\mathrm{A'}=0,\ \mathrm{B'}=0,\ \mathrm{C'}=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12.)$$

Each of these equations being of the general form above given, we shall have by the fundamental theorem,

$$\mathrm{A}=\Sigma(a_m\varepsilon^{m\theta}),\ \mathrm{B}=\Sigma(b_m\varepsilon^{m\theta}),\ \mathrm{C}=\Sigma(c_m\varepsilon^{m\theta}),\ \&c.$$

the successive values of a_m, b_m being connected by a system of relations of the general form,

$$\Sigma(\phi_n(m)a_{m-n})+\Sigma(\psi_n(m)b_{m-n})\ldots=0.$$

To find the lowest value or values of m in a_m, b_m, &c., we must assume a_{m-1}, b_{m-1}, &c. to vanish, whence the last equation gives

$$\phi_0(m)a_m+\psi_0(m)b_m\ldots=0.$$

Now this is the type of the system of relations derived from the term $f_0(\mathrm{D})u$. But the equation $f_0(\mathrm{D})u=0$ is satisfied by the assumption $u=\mathrm{AP}+\mathrm{BQ}\ldots$ in which A, B.. are constants, that is, by the assumption $u=a_0\mathrm{P}+b_0\mathrm{Q}\ldots$, whence the lowest value of m in a_m b_m.. is 0, and the system (12.) is universally satisfied.

Ex. 1. Let the primitive equation be $x^2\frac{d^2u}{dx^2}-\left((a+b-1)x+qx^2\right)\frac{du}{dx}+(ab+cqx)u=0$.

Putting $x=\varepsilon^\theta$, we have

$$\mathrm{D}(\mathrm{D}-1)u-(a+b-1)\mathrm{D}u-q\varepsilon^\theta\mathrm{D}u+(ab+cq\varepsilon^\theta)u=0.$$

Now $q\varepsilon^\theta\mathrm{D}u=q(\mathrm{D}-1)\varepsilon^\theta u$ by (V.), hence we have

$$\{\mathrm{D}(\mathrm{D}-1)-(a+b-1)\mathrm{D}+ab\}u-(q(\mathrm{D}-1)-cq)\varepsilon^\theta u=0,$$

or

$$(\mathrm{D}-a)(\mathrm{D}-b)u-q(\mathrm{D}-c-1)\varepsilon^\theta u=0,$$

which is the symbolical form of the equation, whence $u=\Sigma u_m\varepsilon^{m\theta}$, with the relation

$$(m-a)(m-b)u_m-q(m-c-1)u_{m-1}=0,$$

whence

$$u_m=q\frac{(m-c-1)u_{m-1}}{(m-a)(m-b)}.$$

The equation $(m-a)(m-b)=0$ gives $m=a$ or b, which are consequently the lowest indices of the development. If, therefore, we represent the arbitrary constants u_a, u_b by A and B, we have

$$u=\mathrm{A}\left(x^a+q\frac{a-c}{1(a-b+1)}x^{a+1}+q^2\frac{(a-c)(a-c+1)}{1.2(a-b+1)(a-b+2)}x^{a+2}+\&\mathrm{c}.\right)$$

$$+\mathrm{B}\left(x^b+q\frac{b-c}{1(b-a+1)}x^{b+1}+q^2\frac{(b-c)(b-c+1)}{1.2(b-a+1)(b-a+2)}x^{b+2}+\&\mathrm{c}.\right).$$

Ex. 2. Given $x^3\frac{d^3u}{dx^3}+3x^2\frac{d^2u}{dx^2}+x\frac{du}{dx}+qx^nu=0$, to find u.

Putting $x=\varepsilon^\theta$, we have by (VII.),

$$\{\mathrm{D}(\mathrm{D}-1)(\mathrm{D}-2)+3\mathrm{D}(\mathrm{D}-1)+\mathrm{D}\}u+q\varepsilon^{n\theta}u=0,$$

$$\therefore\ \mathrm{D}^3u+q\varepsilon^{n\theta}u=0.\ \ldots\ldots\ldots\ldots\ldots\ (13.)$$

Now as D represents $\frac{d}{d\theta}$, the equation $\mathrm{D}^3u=0$ gives $u=\mathrm{A}+\mathrm{B}\theta+\mathrm{C}\theta^2$. Substituting this value in (13.), there results

$$\mathrm{D}^3\mathrm{A}+q\varepsilon^{n\theta}\mathrm{A}+(\mathrm{D}^3\mathrm{B}+q\varepsilon^{n\theta}\mathrm{B})\theta+3\mathrm{D}^2\mathrm{B}+(\mathrm{D}^3\mathrm{C}+q\varepsilon^{n\theta}\mathrm{C})\theta^2+6\mathrm{D}^2\mathrm{C}\theta+6\mathrm{DC}=0.$$

Whence by the rule

$$\mathrm{D}^3\mathrm{A}+q\varepsilon^{n\theta}\mathrm{A}+3\mathrm{D}^2\mathrm{B}+6\mathrm{DC}=0,$$

$$\mathrm{D}^3\mathrm{B}+q\varepsilon^{n\theta}\mathrm{B}+6\mathrm{D}^2\mathrm{C}=0,$$

$$\mathrm{D}^3\mathrm{C}+q\varepsilon^{n\theta}\mathrm{C}=0;$$

wherefore by the fundamental theorem

$$\mathrm{A}=\Sigma a_m\varepsilon^{m\theta},\quad \mathrm{B}=\Sigma b_m\varepsilon^{m\theta},\quad \mathrm{C}=\Sigma c_m\varepsilon^{m\theta},$$

$$m^3a_m+qa_{m-n}+3m^2b_m+6mc_m=0,$$
$$m^3b_m+qb_{m-n}+6m^2c_m=0,$$
$$m^3c_m+qc_{m-n}=0,$$

whence we find

$$\left.\begin{aligned} a_m&=-q\frac{m^2a_{m-n}-3mb_{m-n}+12c_{m-n}}{m^5}\\ b_m&=-q\frac{mb_{m-n}-6c_{m-n}}{m^4}\\ c_m&=-q\frac{c_{m-n}}{m^3}. \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (14.)$$

If we now substitute the preceding values of A, B, C in the equation $u=\mathrm{A}+\mathrm{B}\theta+\mathrm{C}\theta^2$, and then change ε^θ into x, θ into $\log x$, we shall have

$$\begin{aligned} u=&(a_0+a_nx^n+a_{2n}x^{2n}\ldots)\\ &+\log x(b_0+b_nx^n+b_{2n}x^{2n}\ldots)\\ &+(\log x)^2(c_0+c_nx^n+c_{2n}x^{2n}\ldots), \end{aligned}$$

a_0, b_0, c_0 being arbitrary, and the succeeding coefficients determined by (14.).

The solution of the linear differential equation $\mathrm{U}=\mathrm{X}$ is found by obtaining a particular integral, and adding to this the complete integral of the equation $\mathrm{U}=0$.

A particular integral of the equation $\mathrm{U}=\mathrm{X}$ will be given by the fundamental theorem whenever X is developable in ascending powers of x. If X is of the form $\mathrm{X}_0+\mathrm{X}_1\log x+\mathrm{X}_2(\log x)^2\ldots+\mathrm{X}_n(\log x)^n$ where X_0, X_1.. are respectively developable in powers of x, we must assume $u=\mathrm{A}+\mathrm{B}\theta\ldots+\mathrm{P}\theta^n$, where A, B...P are variable parameters, to be determined by the fundamental theorem, in the forms $\mathrm{A}=\Sigma a_m\varepsilon^{m\theta}$, $\mathrm{B}=\Sigma b_m\varepsilon^{m\theta}$, &c.

On the same principle we must proceed if such forms as $\cos(n\log x)$, $\sin(n\log x)$, &c. are found in the second member.

Ex. 3. Given $x^2\frac{d^2u}{dx^2}+x\frac{du}{dx}+xu=\log(x)$.

Putting $x=\varepsilon^\theta$, we have

$$\mathrm{D}^2u+\varepsilon^\theta u=\theta.$$

Make $u=\mathrm{A}+\mathrm{B}\theta$, then on reducing

$$\mathrm{D}^2\mathrm{A}+2\mathrm{DB}+\varepsilon^\theta\mathrm{A}+(\mathrm{D}^2\mathrm{B}+\varepsilon^\theta\mathrm{B}-1)\theta=0,$$

whence, as in preceding examples,

$$\mathrm{D}^2\mathrm{A}+2\mathrm{DB}+\varepsilon^\theta\mathrm{A}=0,$$
$$\mathrm{D}^2\mathrm{B}+\varepsilon^\theta\mathrm{B}=1.$$

This system of equations differs from those before considered, in that the second members do not both vanish. The fundamental theorem gives

$$\mathrm{A}=\Sigma a_m\varepsilon^{m\theta},\quad \mathrm{B}=\Sigma b_m\varepsilon^{m\theta},$$
$$\Sigma\{(m^2a_m+2mb_m+a_{m-1})\varepsilon^{m\theta}\}=0,$$
$$\Sigma\{(m^2b_m+b_{m-1})\varepsilon^{m\theta}\}=1,$$

whence $m^2a_m+2mb_m+a_{m-1}=0$ for all values of m, and $m^2b_m+b_{m-1}=0$ for all values of m except $m=0$, which gives $m^2b_m+b_{m-1}=1$, or $b_{-1}=1$; also from the other equation, $a_{-1}=0$. From these, the values of a_m, b_m, corresponding to negative values only of m, may be determined; whence writing x for ϵ^{θ}, and solving the above equations relatively to a_{m-1} and b_{m-1}, we have

$$u=a_{-1}+\frac{a_{-2}}{x}+\frac{a_{-3}}{x^2}+\&c.$$

$$+\log x\left(b_{-1}+\frac{b_{-2}}{x}+\frac{b_{-3}}{x^2}+\&c.\right),$$

where

$$a_{-1}=0,\ b_{-1}=1;$$

and in general

$$a_{m-1}=-(m^2a_m+2mb_m),\ b_{m-1}=-m^2b_m.$$

This is a particular integral; to complete the solution we must add the general value of u given by the equation $x^2\frac{d^2u}{dx^2}+x\frac{du}{dx}+xu=0$, which, as in the preceding examples, is found to be

$$a_0+a_1x+a_2x^2\ldots$$

$$+\log x(b_0+b_1x+b_2x^2\ldots),$$

wherein a_0, b_0 are arbitrary constants, and the succeeding coefficients given by the law

$$a_m=-\frac{ma_{m-1}-2b_{m-1}}{m^3},\quad b_m=-\frac{b_{m-1}}{m^2}.$$

Ex. 4. Given $(x^2+qx^4)\frac{d^2u}{dx^2}+(x+px^2+5qx^3)\frac{du}{dx}+(n^2+px+(4q+r)x^2)u=0.$

On assuming $x=\epsilon^{\theta}$, we get

$$(\mathrm{D}^2+n^2)u+p\mathrm{D}\epsilon^{\theta}u+(q\mathrm{D}^2+r)\epsilon^{2\theta}u=0,\quad\ldots\ldots\quad(15.)$$

which, as a final example, we propose to integrate both by ascending and by descending developments.

The equation $\mathrm{D}^2u+n^2u=0$ gives $u=\mathrm{A}\cos n\theta+\mathrm{B}\sin n\theta$; substituting this value in (15.), and regarding A and B as parameters, we have

$$(\mathrm{D}^2+n^2)u=\cos n\theta(\mathrm{D}^2\mathrm{A}+2n\mathrm{DB})+\sin n\theta(\mathrm{D}^2\mathrm{B}-2n\mathrm{DA})$$

$$p\mathrm{D}\epsilon^{\theta}u=\cos n\theta(p\mathrm{D}\epsilon^{\theta}\mathrm{A}+pn\epsilon^{\theta}\mathrm{B})+\sin n\theta(p\mathrm{D}\epsilon^{\theta}\mathrm{B}-pn\epsilon^{\theta}\mathrm{A})$$

$$q\mathrm{D}^2\epsilon^{2\theta}u=\cos n\theta(-qn^2\epsilon^{2\theta}\mathrm{A}+q\mathrm{D}^2\epsilon^{2\theta}\mathrm{A}+2nq\mathrm{D}\epsilon^{2\theta}\mathrm{B})$$

$$+\sin n\theta(-qn^2\epsilon^{2\theta}\mathrm{B}+q\mathrm{D}^2\epsilon^{2\theta}\mathrm{B}-2nq\mathrm{D}\epsilon^{2\theta}\mathrm{A})$$

$$r\epsilon^{2\theta}u=\cos(n\theta)r\epsilon^{2\theta}\mathrm{A}+\sin(n\theta)r\epsilon^{2\theta}\mathrm{B}.$$

Collecting these results, and equating to 0 the aggregate coefficients of $\cos n\theta$ and $\sin n\theta$,

$$\mathrm{D}^2\mathrm{A}+2n\mathrm{DB}+p(\mathrm{D}\epsilon^{\theta}\mathrm{A}+n\epsilon^{\theta}\mathrm{B})+(q(\mathrm{D}^2-n^2)+r)\epsilon^{2\theta}\mathrm{A}+2nq\mathrm{D}\epsilon^{2\theta}\mathrm{B}=0,$$

$$\mathrm{D}^2\mathrm{B}-2n\mathrm{DA}+p(\mathrm{D}\epsilon^{\theta}\mathrm{A}-n\epsilon^{\theta}\mathrm{B})+(q(\mathrm{D}^2-n^2)+r)\epsilon^{2\theta}\mathrm{B}-2nq\mathrm{D}\epsilon^{2\theta}\mathrm{A}=0;$$

the solution whereof by the fundamental theorem, is

$$A=\Sigma a_m \varepsilon^{m\theta}, \quad B=\Sigma b_m \varepsilon^{m\theta},$$

$$m^2 a_m+2mnb_m+pma_{m-1}+pnb_{m-1}+(q(m^2-n^2)+r)a_{m-2}+2qmnb_{m-2}=0,$$

$$m^2 b_m-2mna_m+pmb_{m-1}-pna_{m-1}+(q(m^2-n^2)+r)b_{m-2}-2qmna_{m-2}=0.$$

Whence making $\varepsilon^{\theta}=x$, and determining the values of a_m, b_m from the two last equations, we have

$$\left.\begin{aligned} u= {} & \cos(n\log x)(a_0+a_1x+a_2x^2+ \&c.) \\ & +\sin(n\log x)(b_0+b_1x+b_2x^2+ \&c.) \end{aligned}\right\} \quad . \; . \; . \; . \; . \; . \; . \quad (16.)$$

a_0 and b_0 being arbitrary, and the remaining coefficients formed on the laws

$$a_m=-\frac{p(m^2+2n^2)a_{m-1}-pmnb_{m-1}+(q(m^2+3n^2)+r)ma_{m-2}+2n(qn^2-r)b_{m-2}}{m(m^2+4n^2)}$$

$$b_m=-\frac{p(m^2+2n^2)b_{m-1}+pmna_{m-1}+(q(m^2+3n^2)+r)mb_{m-2}-2n(qn^2-r)a_{m-2}}{m(m^2+4n^2)}.$$

If $q=0$, $p=0$, $r=1$, we have for the primitive equation

$$x^2\frac{d^2u}{dx^2}+x\frac{du}{dx}+(n^2+x^2)u=0,$$

and for its complete integral,

$$\begin{aligned} u= {} & \cos(n\log x)(a_0+a_2x^2+a_4x^4\ldots) \\ & +\sin(n\log x)(b_0+b_2x^2+b_4x^4\ldots), \end{aligned}$$

where in general

$$a_m=-\frac{ma_{m-2}-2nb_{m-2}}{m(m^2+4n^2)}, \quad b_m=-\frac{mb_{m-2}+2na_{m-2}}{m(m^2+4n^2)}.$$

The above developments terminate in convergency for every value of x. The more general developments (16.) from which they are derived, become, in certain cases, divergent, as is seen by making m infinite in the equations determining a_m, b_m. The descending developments which are then to be employed may be thus obtained.

We have

$$(D^2+n^2)u+pD\varepsilon^{\theta}u+(qD^2+r)\varepsilon^{2\theta}u=0.$$

Multiply by $\varepsilon^{-2\theta}$ and invert the order of the terms, then

$$(q(D+2)^2+r)u+p(D+2)\varepsilon^{-\theta}u+((D+2)^2+n^2)\varepsilon^{-2\theta}u=0.$$

Put $\theta=-\theta_1$, and the above becomes

$$(q(D-2)^2+r)u-p(D-2)\varepsilon^{\theta_1}u+((D-2)^2+n^2)\varepsilon^{2\theta_1}u=0.$$

The equation $(q(D-2)^2+r)u=0$ determines the form of the general solution, which will differ according as $\frac{r}{q}$ shall be positive, negative, or 0. The process is in all respects the same as in the preceding examples, except that in the result we shall have $\varepsilon^{\theta_1}=\frac{1}{x}$.

If $\frac{r}{q}$ is negative, we find

$$u=\frac{1}{x^{2+\sqrt{-\frac{r}{q}}}}\left(a_0+\frac{a_1}{x}+\frac{a_2}{x^2}\ldots\right)+\frac{1}{x^{2-\sqrt{-\frac{r}{q}}}}\left(b_0+\frac{b_1}{x}+\frac{b_2}{x^2}\ldots\right).$$

If $\frac{r}{q}=0$, the solution is of the form

$$u=\frac{1}{x^2}\left\{a_0+\frac{a_1}{x}+\frac{a_2}{x^2}\ldots+\log x(b_0+b_1x+b_2x^2)\right\}.$$

If $\frac{r}{q}$ is positive,

$$u=\frac{1}{x^2}\left\{\cos\left(\sqrt{\frac{r}{q}}\log x\right)\left(a_0+\frac{a_1}{x}+\frac{a_2}{x^2}\ldots\right)+\sin\left(\sqrt{\frac{r}{q}}\log x\right)\left(b_0+\frac{b_1}{x}+\frac{b_2}{x^2}\ldots\right)\right\}.$$

In all these the arbitrary constants are a_0 and b_0, and the values of a_1, b_1, a_2, b_2 are determined by equations similar to those given in the former examples.

Objections are commonly urged against the solutions of linear differential equations in series, on the ground that the condition of convergency is fulfilled only within narrow limits of the independent variable. Might it not be shown that when a solution becomes divergent, there exists another which at the same limit becomes convergent, and that where no second form of solution exists none is needed?

In general the linear differential equation

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\varepsilon^{\theta}u\ldots+f_n(\mathrm{D})\varepsilon^{n\theta}u=0$$

has as many solutions in ascending series as there are simple factors in $f_0(\mathrm{D})$, and as many descending developments as there are factors of a like nature in $f_n(\mathrm{D})$.

B. § 3. *On the Solution of Linear Partial Differential Equations by Series.*

Let x be one of the independent variables, u the dependent variable, and let the particular object proposed be to develope u in ascending powers of x.

Put $x=\varepsilon^{\theta}$, and let the equation, supposed to be wanting of a second member, be placed under the form

$$\mathrm{T}_0u+\mathrm{T}_1\varepsilon^{\theta}u+\mathrm{T}_2\varepsilon^{2\theta}u\ldots=0, \quad \ldots\ldots\ldots \quad (17.)$$

wherein $\mathrm{T}_0, \mathrm{T}_1, \mathrm{T}_2$ are rational and entire functions of D and of the remaining variables x', x'', and of the symbols $\frac{d}{dx'}, \frac{d}{dx''}$.

Should it then happen that T_0 is of the form $f_0(\mathrm{D})$, not involving x', x''.. $\frac{d}{dx'}\,\frac{d}{dx''}$, we shall assume

$$f_0(\mathrm{D})u=0,$$

observing to introduce into the solution of this equation arbitrary functions of x', x'', in the stead of arbitrary constants, and proceed with the result as in the cases already illustrated.

Should T_0 involve x', x'', &c., the operations indicated may be of a kind which it is impossible in the present state of analysis to perform. In some such instances they may be evaded by a linear transformation, and in all cases the difficulty will be placed in the true point of view,—no slight advantage of the method.

The theory of equations involving a second member is, *mutatis mutandis*, the same as explained in the preceding section.

Ex. 1. Let the equation be such, that, on assuming $x=\varepsilon^{\theta}$, we have

$$(D-a)(D-b)u+\varphi(y,\tfrac{d}{dy},D)\varepsilon^{\theta}u=0.$$

Here, by the fundamental theorem,

$$u=\Sigma u_m\varepsilon^{m\theta}=\Sigma u_m x^m,$$

$$(m-a)(m-b)u_m+\varphi(y,\tfrac{d}{dy},m)u_{m-1}=0.$$

The equation $(m-a)(m-b)=0$ gives $m=a$, $m=b$; and as arbitrary functions are to be written in the place of constants, we shall have

$$u=F_a(y)x^a+F_{a+1}(y)x^{a+1}+F_{(a+2)}(y)x^{a+2}\ldots$$
$$+F_b(y)x^b+F_{b+1}(y)x^{b+1}+F_{b+2}(y)x^{b+2}\ldots$$

where $F_a(y)$, $F_b(y)$ are arbitrary, and in general for the rest

$$F_m(y)=\frac{\phi(y,\frac{d}{dy},m)}{(m-a)(m-b)}F_{m-1}(y).$$

As a particular example, let $\frac{d^2u}{dx^2}=f(y)\frac{d^2u}{dy^2}$.

Multiply by x^2, and putting $x=\varepsilon^{\theta}$,

$$D(D-1)u-f(y)\frac{d^2}{dy^2}\varepsilon^{2\theta}u=0.$$

$$\therefore\ u=F_0(y)+\frac{f(y)\frac{d^2}{dy^2}F_0(y)}{1.2}x^2+\frac{\left\{f(y)\frac{d^2}{dy^2}\right\}^2F_0(y)}{1.2.3.4}x^4$$
$$+F_1(y)x+\frac{f(y)\frac{d^2}{dy^2}F_1(y)}{1.2.3}x^3+\frac{\left\{f(y)\frac{d^2}{dy^2}\right\}^2F_1(y)}{1.2.3.4.5}x^5,$$

$F_0(y)F_1(y)$ being arbitrary. As the operation, implied by the symbol $f(y)\frac{d^2}{dy^2}$, can always be performed, the above solution is universally interpretable.

If $f(y)=a^2$, we get

$$u=F_0(y)+\frac{a^2}{1.2}\frac{d^2F_0(y)}{dy^2}x^2+\frac{a^4}{1.2.3.4}\frac{d^4F_0(y)}{dy^4}x^4$$
$$+F_1(y)x+\frac{a^2}{1.2.3}\frac{d^2F_1(y)}{dy^2}x^3+\frac{a^4}{1.2.3.4.5}\frac{d^4F_1(y)}{dy^4}x^5\ldots$$

Put $F_0(y)=\varphi(y)+\psi(y)$, $F_1(y)=u(\varphi'(y)-\psi'(y))$, and substituting, we get

$$u=\varphi(y+ax)+\psi(y-ax),$$

which verifies the solution.

Ex. 2. To integrate the equation $x^2\frac{d^2u}{dx^2}+x\frac{du}{dx}-f(y)\frac{d^2u}{dy^2}=0$.

Putting $x=\varepsilon^{\theta}$, we have

$$D^2u-f(y)\frac{d^2}{dy^2}\varepsilon^{2\theta}=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18.)$$

The equation $D^2u=0$ gives $u=a+B\theta$, which we shall substitute in (18.), regarding A and B as functions of θ and y. This gives

$$D^2A+\theta D^2B+2DB-f(y)\frac{d^2}{dy^2}(\varepsilon^{2\theta}A+\theta\varepsilon^{2\theta}B)=0,$$

whence by the rule

$$D^2A+2DB-f(y)\frac{d^2}{dy^2}\varepsilon^{2\theta}A=0,$$

$$D^2B-f(y)\frac{d^2}{dy^2}\varepsilon^{2\theta}B=0,$$

applied to which, the fundamental theorem gives

$$A=\Sigma a_m\varepsilon^{m\theta}, \quad B=\Sigma b_m\varepsilon^{m\theta},$$

$$m^2a_m+2m\,b_m-f(y)\frac{d^2}{dy^2}a_{m-2}=0,$$

$$m^2b_m-f(y)\frac{d^2}{dy^2}b_{m-2}=0;$$

whence writing x for ε^{θ}, and determining a_m, b_m; observing also that a_0, b_0 will be arbitrary functions of y, we have

$$u=\phi_0(y)+\phi_1(y)x+\phi_2(y)x^2+\text{ \&c.}$$
$$+\log x(\psi_0(y)+\psi_1(y)x+\psi_2(y)x^2+\text{ \&c.}),$$

$\phi_0(y)$, $\phi_1(y)$ being arbitrary, and the succeeding forms of $\phi_m(y)$, $\psi_m(y)$ determined by the equations

$$\phi_m(y)=f(y)\frac{d^2}{dy^2}\frac{m\phi_{m-2}(y)-2\psi_{m-2}(y)}{m^3}$$

$$\psi_m(y)=f(y)\frac{d^2}{dy^2}\psi_{m-2}(y).$$

Euler has exhibited in a series the integral of the equation

$$\frac{d^2u}{dxdy}+\frac{a}{x+y}\left(\frac{du}{dx}+\frac{du}{dy}\right)+\frac{b}{(x+y)^2}u=0,$$

and on that result are founded many of the solutions of partial differential equations in Dr. Peacock's 'Examples.' We proceed to consider a somewhat more general equation, of which we shall give two distinct solutions.

Ex. 3. Given $\frac{d^2u}{dxdy}+f_1(x+y)\frac{du}{dx}+f_2(x+y)\frac{du}{dy}+f_3(x+y)u=0$,

f_1, f_2, f_3 denoting any functions whatever, to find u.

Put $x=s$, $x+y=t$, then $\frac{d}{dx}=\frac{d}{ds}+\frac{d}{dt}$, $\frac{d}{dy}=\frac{d}{dt}$, and transforming, we have

$$\frac{d^2u}{dsdt}+\frac{d^2u}{dt^2}+f_1(t)\frac{du}{ds}+(f_1(t)+f_2(t))\frac{du}{dt}+f_3(t)u=0.$$

Multiply by s, and put $s=\epsilon^{\theta}$, we have

$$\left(\frac{d}{dt}+f_1(t)\right)\mathrm{D}u+\left(\frac{d^2}{dt^2}+(f_1(t)+f_2(t))\frac{d}{dt}+f_3(t)\right)\epsilon^{\theta}u=0\,;$$

whence, by the fundamental theorem,

$$u=\Sigma u_m\epsilon^{m\theta}=\Sigma u_m x^m,$$

$$\left(\frac{d}{dt}+f_1(t)\right)mu_m+\left(\frac{d^2}{dt^2}+(f_1(t)+f_2(t))\frac{d}{dt}+f_3(t)\right)u_{m-1}=0.$$

Hence, if for u_m we write $\mathrm{F}_m(t)$, the solution will assume the following form,

$$u=\mathrm{F}_0(t)+\mathrm{F}_1(t)x+\mathrm{F}_2(t)x^2, \quad \ldots\ldots\ldots \quad (19.)$$

where $\mathrm{F}_0(t)$ is arbitrary, and in general

$$\frac{d}{dt}\mathrm{F}_m(t)+f_1(t)\mathrm{F}_m(t)=-\frac{\left(\frac{d^2}{dt^2}+(f_1(t)+f_2(t))\frac{d}{dt}+f_3(t)\right)\mathrm{F}_{m-1}(t)}{m},$$

whence we have, as the law of derivation,

$$\mathrm{F}_m(t)=-\frac{1}{m}\epsilon^{-\int f_1(t)dt}\int\epsilon^{\int f_1(t)dt}\left(\frac{d^2}{dt^2}+(f_1(t)+f_2(t))\frac{d}{dt}+f_3(t)\right)\mathrm{F}_{m-1}(t)dt.$$

To this we may add a precisely similar solution in ascending powers of y, the two together constituting the complete integral.

We cannot, from the above, deduce Euler's solution, because that solution is expressed in ascending powers of t, and not of x or y. If, however, for $f_1(t)$, $f_2(t)$, $f_3(t)$ we substitute Euler's forms of those functions, and make $t=\epsilon^{\theta}$, we shall obtain the result in question.

The general solution (19.) has been given in order to illustrate the fact before adverted to, that when T_0 of (17.) is not simply a function of D, the derivation of the coefficients of the final series may involve operations which it is difficult to perform.

We shall now show how, by a linear transformation, the difficulty may be evaded.

Assume $x-y=s$, $x+y=t$, then $\frac{d}{dx}=\frac{d}{ds}\frac{ds}{dx}+\frac{d}{dt}\frac{dt}{dx}=\frac{d}{ds}+\frac{d}{dt}$,

and
$$\frac{d}{dy}=\frac{d}{ds}\frac{ds}{dy}+\frac{d}{dt}\frac{dt}{dy}=\frac{d}{dt}-\frac{d}{ds},$$

and transforming the original equation, we find

$$\frac{d^2u}{ds^2}-\frac{d^2u}{dt^2}-(f_1(t)-f_2(t))\frac{du}{ds}-(f_1(t)+f_2(t))\frac{du}{dt}-f_3(t)u=0.$$

Multiply by s^2 and make $s=\epsilon^{\theta}$, we have, on reduction,

$$\mathrm{D}(\mathrm{D}-1)u-(f_1(t)-f_2(t))(\mathrm{D}-1)\epsilon^{\theta}u-\left(\frac{d^2}{dt^2}+(f_1(t)+f_2(t))\frac{d}{dt}+f_3(t)\right)\epsilon^{2\theta}u=0,$$

whence, by the fundamental theorem,

$$u=\Sigma u_m \varepsilon^{m\theta}=\Sigma u_m s^{m},$$

$$m(m-1)u_m-(f_1(t)-f_2(t))(m-1)u_{m-1}-\left(\frac{d^2}{dt^2}+(f_1(t)+f_2(t)\frac{d}{dt}+f_3(t)\right)u_{m-2}=0. . \quad (20.)$$

The equation $m(m-1)=0$ gives $m=0$ or 1, whence u_0 and u_1 are arbitrary functions of t, which we shall represent by $F_0(t)$, $F_1(t)$. The value of u_m, which we shall similarly represent by $F_m(t)$, is given by (20.), whence the complete integral will be

$$u=F_0(t)-F_1(t)s+F_2(t)s^2+F_3(t)s^3 \ldots \textit{ad inf.},$$

wherein $s=x-y$, $t=x+y$, $F_0(t)$, $F_1(t)$ are arbitrary, and in general

$$F_m(t)=\frac{(m-1)(f_1(t)-f_2(t))F_{m-1}(t)+\left(\frac{d^2}{dt^2}+(f_1(t)+f_2(t))\frac{d}{dt}+f_3(t)\right)F_{m-2}(t)}{m(m-1)}.$$

The derivation of the coefficients is thus always possible.

B. § 4. *On the Integration of Linear Differential Equations in Finite Terms.*

If we affect both sides of the equation

$$f_0(D)u+f_1(D)\varepsilon^{\theta}u \ldots +f_n(D)\varepsilon^{n\theta}u=U$$

with $\{f_0(D)\}^{-1}$, and for $\frac{f_1(D)}{f_0(D)}, \frac{f_2(D)}{f_0(D)} . .$ write ϕ_1, (D), $\phi_2(D) . .$, and for $\{f_0(D)\}^{-1}U$ write U, we have

$$u+\phi_1(D)\varepsilon^{\theta}u \ldots +\phi_n(D)\varepsilon^{n\theta}u=U\,; \quad . \; . \; . \; . \; . \; . \; . \quad (21.)$$

under which form the linear differential equation will be treated in the following investigation.

We however premise the integrability of equations of the form

$$F\left(f(x)\frac{d}{dx}\right)u=U,$$

for, writing $f(x)\frac{d}{dx}=\frac{d}{dt}$, whence $t=\int\frac{dx}{f(x)}$, we have

$$F\left(\frac{d}{dt}\right)u=U,$$

which, for the forms of F here contemplated, is an equation with constant coefficients.

The linear equation of the first order is an example of the above class, for, writing it in the form

$$P\frac{du}{dx}+u=Q,$$

we have only to assume $P\frac{d}{dx}=\frac{d}{dt}$, in order to obtain

$$t=\int\frac{dx}{P}, \quad \frac{du}{dt}+u=Q,$$

$$\therefore \quad u=\varepsilon^{-t}\int\varepsilon^{t}Q\,dt=\varepsilon^{-\int\frac{dx}{P}}\int\varepsilon^{\int\frac{dx}{P}}\frac{Q}{P}dx.$$

Equations of the second order comprised in the above general class are of the form

$$\{f(x)\}^2\frac{d^2u}{dx^2}+f(x)(f'(x)+p)\frac{du}{dx}+qu=\mathrm{U}, \quad \ldots\ldots \quad (22.)$$

as is found by writing $f(x)\frac{d}{dx}=\frac{d}{dt}$ in the equation

$$\frac{d^2u}{dt^2}+p\frac{du}{dt}+qu=\mathrm{U},$$

whence $t=\int\frac{dx}{f(x)}$.

The equation $(1+ax^2)\frac{d^2u}{dx^2}+ax\frac{du}{dx}\pm n^2u=0$ is a particular case of (22.), and its solution is determined by the system

$$t=\int\frac{dx}{\sqrt{1+ax^2}},\ \frac{d^2u}{dt^2}\pm n^2u=0.$$

The symbolical form of the equation just considered is

$$u+\frac{a(\mathrm{D}-2)^2\pm n^2}{\mathrm{D}(\mathrm{D}-1)}\varepsilon^{2\theta}u=0; \quad \ldots\ldots\ldots \quad (23.)$$

to which we shall have occasion to refer.

In the employment of the general symbolical form of the linear differential equation, two principal cases will be considered; the first comprising such equations as are reducible to a system of an inferior order, by a method of resolution similar to that which is employed in the solution of linear differential equations with constant coefficients; the second including those whose solution depends on a transformation affecting the dependent variable u. A more general method of resolution will be explained in the sequel.

Proposition 1.—The equation

$$u+a_1\phi(\mathrm{D})\varepsilon^{\theta}u+a_2\phi(\mathrm{D})\phi(\mathrm{D}-1)\varepsilon^{2\theta}u\ldots+a_n\phi(\mathrm{D})\phi(\mathrm{D}-1)..\phi(\mathrm{D}-n+1)\varepsilon^{n\theta}u=\mathrm{U}$$

may be resolved into a system of equations of the form

$$u-q\phi(\mathrm{D})\varepsilon^{\theta}u=\mathrm{U},$$

the values of q being determined by the equation

$$q^n+a_1q^{n-1}+a_2q^{n-2}\ldots+a_n=0. \quad \ldots\ldots\ldots \quad (\mathrm{XII.})$$

For

$$\phi(\mathrm{D})\phi(\mathrm{D}-1)\varepsilon^{2\theta}u=\phi(\mathrm{D})\varepsilon^{\theta}\phi(\mathrm{D})\varepsilon^{\theta}u=\{\phi(\mathrm{D})\varepsilon^{\theta}\}^2u,$$

and in general

$$\phi(\mathrm{D})\phi(\mathrm{D}-1)..\phi(\mathrm{D}-n+1)\varepsilon^{n\theta}u=\{\phi(\mathrm{D})\varepsilon^{\theta}\}^nu;$$

so that if we represent the symbol $\phi(\mathrm{D})\varepsilon^{\theta}$ by ρ, the equation in question becomes

$$(1+a_1\rho+a_2\rho^2\ldots+a_n\rho^n)u=\mathrm{U};$$

$$\begin{aligned}\therefore\quad u&=(1+a_1\rho+a_2\rho^2\ldots+a_n\rho^n)^{-1}\mathrm{U}\\&=\{\mathrm{N}_1(1-q_1\rho)^{-1}+\mathrm{N}_2(1-q_2\rho)^{-1}..+\mathrm{N}_n(1-q_n\rho)^{-1}\}\mathrm{U},\end{aligned}$$

provided that $q_1, q_2.., q_n$ are roots of the equation

$$q^n+a_1q^{n-1}+a_2q^{n-2}..+a_n=0,$$

and that $N_1, N_2,..N_n$ are of the forms

$$N_1=\frac{q_1^{n-1}}{(q_1-q_2)(q_1-q_3)..(q_1-q_n)}...N_n=\frac{q_n^{n-1}}{(q_n-q_1)(q_n-q_2)..(q_n-q_{n-1})}.$$

Let $(1-q_1\rho)^{-1}U=u_1$, $(1-q_2\rho)^{-1}U=u_2$, and so on, then

$$u_1-q_1\rho u_1=U, \text{ or } u_1-q_1\varphi(D)\epsilon^{\theta}u_1=U,$$

whence $$u=N_1u_1+N_2u_2...+N_nu_n, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (24.)$$

wherein $u_1u_2..u_n$ are determined by the system of equations,

$$\left.\begin{array}{l} u_1-q_1\varphi(D)\epsilon^{\theta}u_1=U, \\ u_2-q_2\varphi(D)\epsilon^{\theta}u_2=U, \\ . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \\ u_n-q_n\varphi(D)\epsilon^{\theta}u_n=U. \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25.)$$

The forms of $\varphi(D)$ which render the above system integrable will hereafter be determined. The most important of these is obviously

$$\varphi(D)=\frac{a_1D+b_1}{aD+b},$$

which reduces the proposed system of equations to the first order.

For the particular form $\varphi(D)=(D)^{-1}$, the equation above considered will represent the general linear differential equation with constant coefficients; for every other form of $\varphi(D)$ it will represent an equation with variable coefficients.

Ex. Let the given equation be $(x^2+mx^3+nx^4)\frac{d^2u}{dx^2}$

$$+(2bx+(a+b+2)mx^2+(2a+4)nx^3)\frac{du}{dx}+(b(b-1)+(a+1)bmx+(a+2)(a+1)nx^2)u=0.$$

Putting $x=\epsilon^{\theta}$, and reducing to the symbolical form, we have

$$u+m\frac{D+a}{D+b}\epsilon^{\theta}u+n\frac{(D+a)(D+a-1)}{(D+b)(D+b-1)}\epsilon^{2\theta}u=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26.)$$

Here q_1, q_2 are the roots of the equation $q^2+mq+n=0$, whence

$$u=\frac{q_1u_1}{q_1-q_2}+\frac{q_2u_2}{q_2-q_1}=\frac{q_1u_1-q_2u_2}{q_1-q_2},$$

u_1 and u_2 being given by the equations

$$u_1-q_1\frac{D+a}{D+b}\epsilon^{\theta}u_1=0,$$

$$u_2-q_2\frac{D+a}{D+b}\epsilon^{\theta}u_2=0.$$

From the former of these equations we have

$$(\mathrm{D}+b)u_1-q_1(\mathrm{D}+a)\epsilon^{\theta}u_1=0,$$

$$(\mathrm{D}+b)u_1-q_1\epsilon^{\theta}(\mathrm{D}+a+1)u=0,$$

$$\left(x\frac{d}{dx}+b\right)u_1-q_1x\left(x\frac{d}{dx}+a+1\right)u_1=0,$$

$$(x-q_1x^2)\frac{du_1}{dx}+(b-(a+1)q_1x)u_1=0,$$

$$u_1=\frac{c_1}{x^b(1-q_1x)^{a-b+1}},\quad u_2=\frac{c_2}{x^b(1-q_2x)^{a-b+1}},$$

$$\therefore\ u=\frac{c_1(1-q_2x)^{a-b+1}+c_2(1-q_1x)^{a-b+1}}{x^b(1-q_1x)^{a-b+1}(1-q_2x)^{a-b+1}}.$$

The same process would solve the same equation with a second member X.

The next class of equations to be considered comprises those which are integrable by a transformation operating on the dependent variable.

As the theory of the general equation

$$u+\phi_1(\mathrm{D})\epsilon^{\theta}u+\phi_2(\mathrm{D})\epsilon^{2\theta}u\ \ldots+\phi_n(\mathrm{D})\epsilon^{n\theta}u=\mathrm{U}$$

is deducible from that of the equation

$$u+\phi(\mathrm{D})\epsilon^{r\theta}u=\mathrm{U},$$

we shall first consider the simple case.

Proposition 2.—*The equation* $u+\phi(\mathrm{D})\epsilon^{r\theta}u=\mathrm{U}$ *will be converted into the form* $v+\phi(\mathrm{D}+n)\epsilon^{r\theta}v=\mathrm{V}$, *by the relations*

$$u=\epsilon^{n\theta}v,\quad \mathrm{U}=\epsilon^{n\theta}\mathrm{V}.\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ (\text{XIII.})$$

For assume $u=\epsilon^{n\theta}v$, and substituting in the original equation, we have

$$\epsilon^{n\theta}v+\phi(\mathrm{D})\epsilon^{(n+r)\theta}v=\mathrm{U},$$

$$\therefore\quad \epsilon^{n\theta}v+\epsilon^{n\theta}\phi(\mathrm{D}+n)\epsilon^{r\theta}v=\mathrm{U},\text{ by (V.)},$$

$$v+\phi(\mathrm{D}+n)\epsilon^{r\theta}v=\epsilon^{-n\theta}\mathrm{U}.$$

Let $\epsilon^{-n\theta}\mathrm{U}=\mathrm{V}$, then $\mathrm{U}=\epsilon^{n\theta}\mathrm{V}$, and the above becomes

$$v+\phi(\mathrm{D}+n)\epsilon^{r\theta}v=\mathrm{V},$$

as was to be shown.

Proposition 3.—*The equation* $u+\phi(\mathrm{D})\epsilon^{r\theta}u=\mathrm{U}$ *will be converted into the form* $v+\psi(\mathrm{D})\epsilon^{r\theta}v=\mathrm{V}$, *by the relations*

$$u=\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}v,\quad \mathrm{U}=\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}\mathrm{V},$$

wherein $\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}$ *denotes the infinite symbolical product* $\frac{\phi(\mathrm{D})\phi(\mathrm{D}-r)\phi(\mathrm{D}-2r)\ldots}{\psi(\mathrm{D})\psi(\mathrm{D}-r)\psi(\mathrm{D}-2r)\ldots}$ . . (XIV.)

For assume $u=f(\mathrm{D})v$, and substituting in the original equation, we have

$$f(\mathrm{D})v+\phi(\mathrm{D})\epsilon^{r\theta}f(\mathrm{D})v=\mathrm{U},$$

$$\therefore\ f(\mathrm{D})v+\phi(\mathrm{D})f(\mathrm{D}-r)\epsilon^{r\theta}v=\mathrm{U}\text{ by (V.)},$$

$$v+\frac{\phi(\mathrm{D})f(\mathrm{D}-r)}{f(\mathrm{D})}\epsilon^{r\theta}v=\{f(\mathrm{D})\}^{-1}\mathrm{U}.\ .\ .\ .\ .\ .\ .\ .\ \ (27.)$$

Comparing this with the equation $v+\psi(\mathrm{D})\epsilon^{r\theta}v=\mathrm{V}$, we have

$$\frac{\phi(\mathrm{D})f(\mathrm{D}-r)}{f(\mathrm{D})}=\psi(\mathrm{D}),$$

$$\therefore\ f(\mathrm{D})=\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}f(\mathrm{D}-r)\,;\ .\ .\ .\ .\ .\ .\ .\ .\ .\ \ (28.)$$

hence
$$f(\mathrm{D}-r)=\frac{\phi(\mathrm{D}-r)}{\psi(\mathrm{D}-r)}f(\mathrm{D}-2r),$$

and so on, wherefore the value of $f(\mathrm{D})$ will be represented by the infinite product $\frac{\phi(\mathrm{D})\phi(\mathrm{D}-r)\phi(\mathrm{D}-2r)\ldots}{\psi(\mathrm{D})\psi(\mathrm{D}-r)\psi(\mathrm{D}-2r)\ldots}$, which we shall express under the form $\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}$, in accordance with Sir John Herschel's notation for the integrals of equations of finite differences of the first order, of which, in fact, (28.) is an example. Hence (27.) becomes

$$v+\psi(\mathrm{D})\epsilon^{r\theta}v=\mathrm{V},$$

with the relations

$$u=\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}v,\quad \mathrm{U}=\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}\mathrm{V}.$$

As the above Proposition is of great importance in the solution of differential equations, we shall devote some attention to the circumstances which attend its application.

That the expression of $\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}$ may be finite, it is sufficient that for every elementary factor $\chi(\mathrm{D})$ occurring in the numerator, there should correspond a similar factor $\chi(\mathrm{D}\pm ir)$ in the denominator, i being an integer, and *vice versâ*; for

$$\mathrm{P}_r\frac{\chi(\mathrm{D})}{\chi(\mathrm{D}+ir)}=\frac{\chi(\mathrm{D})\chi(\mathrm{D}-r)\chi(\mathrm{D}-2r)\ldots}{\chi(\mathrm{D}+ir)\chi(\mathrm{D}+(i-1)r)\ldots}$$
$$=\frac{1}{\chi(\mathrm{D}+ir)\chi(\mathrm{D}+(i-1)r)\,..\,\chi(\mathrm{D}+r)},$$

which is a finite expression. Again,

$$\mathrm{P}_r\frac{\chi(\mathrm{D})}{\chi(\mathrm{D}-ir)}=\frac{\chi(\mathrm{D})\chi(\mathrm{D}-r)\ldots}{\chi(\mathrm{D}-ir)\chi(\mathrm{D}-(i+1)r)\ldots}$$
$$=\chi(\mathrm{D})\chi(\mathrm{D}-r)\,..\,\chi(\mathrm{D}-(i-1)r),$$

which is also finite; the product of any number of such expressions is finite also.

If $\chi(\mathrm{D})$ is any elementary factor of $\phi(\mathrm{D})$, it may be converted into $\chi(\mathrm{D}\pm ir)$; for let $\phi(\mathrm{D})=\chi(\mathrm{D})\chi^1(\mathrm{D})$, and let $\psi(\mathrm{D})=\chi(\mathrm{D}\pm ir)\chi^1(\mathrm{D})$, wherein $\chi^1(\mathrm{D})$ denotes the product of the remaining factors, then

$$\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}=\mathrm{P}_r\frac{\chi(\mathrm{D})}{\chi(\mathrm{D}\pm ir)},$$

which is finite.

If $\varphi(\mathrm{D})$ involves any factor of the form $\frac{\chi(\mathrm{D})}{\chi(\mathrm{D}\pm ir)}$, it may be made to disappear; for let $\varphi(\mathrm{D})=\frac{\chi(\mathrm{D})}{\chi(\mathrm{D}\pm ir)}\chi'(\mathrm{D})$, and let $\psi(\mathrm{D})=\chi'(\mathrm{D})$, then

$$\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}=\mathrm{P}_r\frac{\chi(\mathrm{D})}{\chi(\mathrm{D}\pm ir)},$$

which is finite.

From inspection of the above it is evident that if $\varphi(\mathrm{D})$ is in the form of a rational fraction, and it is proposed to diminish (so to speak) D in any factor of the numerator, or to augment D in a factor of the denominator, by a multiple of r, the process by which u will be finally deduced from v will depend upon differentiation; but if it is proposed to augment D in a factor of the numerator, or to diminish D in a factor of the denominator, the process will involve integration. The former is obviously the preferable condition.

The general proposition (XIV.) amounts in reality to this, that the equation

$$u+\varphi(\mathrm{D})\varepsilon^{r\theta}u=\mathrm{U} \quad \ldots\ldots\ldots\ldots \quad (29.)$$

may be resolved into the system of equations,

$$u=\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}v, \quad \mathrm{U}=\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}\mathrm{V}, \quad \ldots\ldots\ldots \quad (30.)$$

$$v+\psi(\mathrm{D})\varepsilon^{r\theta}v=\mathrm{V}, \quad \ldots\ldots\ldots\ldots \quad (31.)$$

whence V, v, u are to be successively determined. Of these equations we shall call the two first the auxiliary ones, and (31.) the transformed one. This premised, the following are the canons which regulate the determination of the constants.

1. If no factor of $\varphi(\mathrm{D})$ disappears in $\psi(\mathrm{D})$, no arbitrary constants are to be introduced into the solutions of the auxiliary equations; those derived from the transformed equation being necessary and sufficient.

2. Disappearing factors are in general of the form $\frac{\mathrm{D}+a}{\mathrm{D}+b}$, $a-b$ being a multiple of r. Every such factor will give a system of $\frac{a-b}{r}$ constants in the solution of one of the auxiliary equations; if in that of the equation determining V, those constants will be arbitrary, but one only will need to be retained; if however in that of the equation determining u, one only will be arbitrary, and the rest will be therewith connected by the relation $u_m+\varphi(m)u_{m-r}=0$, derived from the primitive equation.

The reason why the constants connected with the disappearing factor are arbitrary in V alone, is, that V enters into no other equation than the one in whose solution those constants are found. If however the entire series of constants in V are retained, they will be reduced to one by the subsequent differentiations in passing to the value of u.

Ex. 1. To determine the general characteristic of those differential equations of the nth degree, the solution of which depends on that of the equation $\frac{d^nv}{dx^n}\pm q^nv=\mathrm{X}$.

The symbolical form of this equation is

$$v \pm \frac{q^n}{D(D-1)\,..\,(D-n+1)}\varepsilon^{n\theta}v = V, \qquad \text{. . . . . (32.)}$$

wherein V is the symbolical form of $\left(\frac{d}{dx}\right)^{-n}X$, *i. e.* the result obtained by writing ε^{θ} for x in the nth integral of Xdx^n, no constants being added in the integration. From inspection of (32.), it is evident that the class of equations sought, must, on assuming $x=\varepsilon^{\theta}$, be reducible to the form

$$u \pm \frac{q^n}{(D+a_1)(D+a_2)\,..\,(D+a_n)}\varepsilon^{n\theta}u = U,$$

in which we shall suppose the quantities a_1, a_2, .. a_n to be ranged in the order of their magnitudes. Put $u=\varepsilon^{-a_1\theta}u$, then by Prop. 2,

$$u_1 \pm \frac{q^n}{D(D+a_2-a_1)\,..\,(D+a_n-a_1)}\varepsilon^{n\theta}u_1 = \varepsilon^{a_1\theta}U. \qquad \text{. . . . . . (33.)}$$

The first factor of the denominator of $\phi(D)$ in (32.) now corresponds with the first factor of the denominator of $\psi(D)$ in (33.). In any of the remaining factors we may by Prop. 2 convert D into $D \pm ir$, i being any integer,—hence that they may all correspond with the factors of $\psi(D)$, we must have the quantities

$$\frac{a_2-a_1+1}{n}, \quad \frac{a_3-a_1+2}{n}, \quad \frac{a_4-a_1+3}{n} \ldots\ldots \frac{a_n-a_1+n-1}{n},$$

all negative integers, which are therefore the conditions sought.

From (32.) and (33.), by (XIV.),

$$u_1 = P_n \frac{\phi(D)}{\psi(D)}v,$$

wherein $\phi(D) = \pm \frac{q^n}{D(D+a_2-a_1)\,..\,(D+a_n-a_1)}$, $\psi(D) = \pm \frac{q^n}{D(D-1)\,..\,(D-n+1)}$;

but $u=\varepsilon^{-a_1\theta}u_1$, wherefore

$$u = \varepsilon^{-a_1\theta}P_n \frac{(D-1)\,..\,(D-n+1)}{(D+a_2-a_1)\,..\,(D+a_n-a_1)}v, \qquad \text{. . . . . (34.)}$$

whence the value of u will be deduced from that of v by *differentiation*; for since $a_2-a_1<-1$,

$$P_n \frac{(D-1)}{(D+a_2-a_1)} = (D-1)(D-n-1)\,..\,(D+a_2-a_1+n),$$

and so on for the remaining factors to which P_n is to be applied.

The two following examples will sufficiently illustrate the preceding case.

Ex. 2. Given $\frac{d^2u}{dx^2}+q^2u-\frac{6u}{x^2}=0$, which is an equation occurring in the theory of the earth's figure.

The symbolical form of this equation is

$$u + \frac{q^2}{(D+2)(D-3)}\varepsilon^{2\theta}u = 0.$$

Here $a_1=2$, $a_2=-3$, $n=2$; also the equation for v is $\frac{d^2v}{dx^2}+q^2v=0$, whence

$$v=c\sin(qx+c_1)\text{; and by (34.),}$$

$$u=\varepsilon^{-2\theta}\mathrm{P}_2\frac{\mathrm{D}-1}{\mathrm{D}-5}v,$$

$$=\varepsilon^{-2\theta}(\mathrm{D}-1)(\mathrm{D}-3)v,$$

$$=\frac{1}{x^2}\left(x^2\frac{d^2}{dx^2}-3x\frac{d}{dx}+3\right)c\sin(qx+c_1),$$

$$=c\left\{\left(\frac{3}{x^2}-q^2\right)\sin(qx+c_1)-\frac{3q}{x}\cos(qx+c_1)\right\}.$$

The above example might have been treated directly by Prop. 3, and without the aid of Prop. 2, but the final determination of u would not have then depended on differentiation alone. Thus we should have had

$$u+\frac{q^2}{(\mathrm{D}+2)(\mathrm{D}-3)}\varepsilon^{2\theta}u=0,$$

$$v+\frac{q^2}{\mathrm{D}(\mathrm{D}-1)}\varepsilon^{2\theta}u=\mathrm{V}.$$

Here $\varphi(\mathrm{D})=\frac{q^2}{(\mathrm{D}+2)(\mathrm{D}-3)}$, $\psi(\mathrm{D})=\frac{q^2}{\mathrm{D}(\mathrm{D}-1)}$, whence $\mathrm{P}_2\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}=\mathrm{P}_2\frac{\mathrm{D}(\mathrm{D}-1)}{(\mathrm{D}+2)(\mathrm{D}-3)}=\frac{\mathrm{D}-1}{\mathrm{D}+2}$, wherefore by (30.),

$$u=\frac{\mathrm{D}-1}{\mathrm{D}+2}v, \qquad 0=\frac{\mathrm{D}-1}{\mathrm{D}+2}\mathrm{V}.$$

As no factors disappear in $\psi(\mathrm{D})$, no constants are to be added in determining V, whence $\mathrm{V}=0$, $v=c\sin(qx+c_1)$,

$$u=\frac{\mathrm{D}-1}{\mathrm{D}+2}v=(1-3(\mathrm{D}+2)^{-1})c\sin(qx+c_1),$$

$$=c(1-3\varepsilon^{-2\theta}(\mathrm{D})^{-1}\varepsilon^{2\theta})\sin(qx+c_1),$$

$$=c\left(1-\frac{3}{x^2}\left(x\frac{d}{dx}\right)^{-1}x^2\right)\sin(qx+c_1),$$

$$=c\{\sin(qx+c_1)-\frac{3}{x^2}\int dx\,x\sin(qx+c_1)\},$$

$$=c\left\{\left(1-\frac{3}{q^2x^2}\right)\sin(qx+c_1)+\frac{3}{qx}\cos(qx+c_1)\right\}.$$

Ex. 3. Given the equation $\frac{d^2u}{dx^2}-\frac{i(i+1)}{x^2}u\pm h^2u=0$, i being a positive integer.

This equation, under a slightly different form, has been discussed by Mossotti in his memoir on Molecular Action. It has also been treated by Paoli and by Plana.

The symbolical form of the equation is

$$u\pm\frac{h^2}{(\mathrm{D}+i)(\mathrm{D}-i-1)}\varepsilon^{2\theta}u=0. \quad \ldots\ldots\ldots (35.)$$

Comparing this with the general form of Ex. 1, we have

$$a_1=i,\ a_2=-i-1,\ n=2,\ q=h, \text{ whence}$$

$$u=\varepsilon^{-i\theta}\mathrm{P}_2\frac{\mathrm{D}-1}{\mathrm{D}-2i-1}v,$$

v being determined by the equation $\frac{d^2v}{dx^2}\pm h^2v=0$. Now $\mathrm{P}_2\frac{\mathrm{D}-1}{\mathrm{D}-2i-1}=(\mathrm{D}-1)(\mathrm{D}-3)..(\mathrm{D}-2i+1)$, and writing $x\frac{d}{dx}$ for D, we have

$$u=\frac{1}{x^i}\left(x\frac{d}{dx}-1\right)\left(x\frac{d}{dx}-3\right)..\left(x\frac{d}{dx}-2i+1\right)v. \quad . \quad . \quad . \quad . \quad . \quad (36.)$$

The value of u may be otherwise expressed thus. Applied to any subject, we have

$$\mathrm{D}-1=\varepsilon^{\theta}\mathrm{D}\varepsilon^{-\theta}=x\left(x\frac{d}{dx}\right)\frac{1}{x}=x^2\frac{d}{dx}\frac{1}{x},$$

$$\mathrm{D}-3=\varepsilon^{3\theta}\mathrm{D}\varepsilon^{-3\theta}=x^4\frac{d}{dx}\frac{1}{x^3},$$

$$\mathrm{D}-2i+1=\varepsilon^{(2i-1)\theta}\mathrm{D}\varepsilon^{-(2i-1)\theta}=x^{2i}\frac{d}{dx}x^{-(2i-1)}.$$

Substituting these expressions in the general value of u, viz.

$$u=\varepsilon^{-i\theta}(\mathrm{D}-1)(\mathrm{D}-3)..(\mathrm{D}-2i+1)v,$$

we find

$$u=\frac{1}{x^i}\left(x^2\frac{d}{dx}\right)\frac{1}{x}\left(x^4\frac{d}{dx}\right)\frac{1}{x^3}\ldots\left(x^{2i}\frac{d}{dx}\right)x^{-(2i-1)}v,$$

$$=\frac{1}{x^{i+1}}\left(x^3\frac{d}{dx}\right)\left(x^3\frac{d}{dx}\right)..\left(x^3\frac{d}{dx}\right)\frac{v}{x^{2i-1}},$$

$$=\frac{1}{x^{i+1}}\left(x^3\frac{d}{dx}\right)^i\frac{v}{x^{2i-1}}.$$

Hence the complete integral of the equation $\frac{d^2u}{dx^2}-\frac{i(i+1)}{x^2}u+h^2u=0$ is

$$u=\frac{1}{x^{i+1}}\left(x^3\frac{d}{dx}\right)^i\frac{c\cos(hx)+c_1\sin(hx)}{x^{2i-1}};$$

and that of the equation $\frac{d^2u}{dx^2}-\frac{i(i+1)}{x^2}u-h^2u=0$ is

$$u=\frac{1}{x^{i+1}}\left(x^3\frac{d}{dx}\right)^i\frac{c\varepsilon^{hx}+c_1\varepsilon^{-hx}}{x^{2i-1}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (37.)$$

which forms are perhaps new.

Equations of the above class have been discussed by Mr. Leslie Ellis, in two very ingenious papers published in the Cambridge Mathematical Journal*, and it is just to observe that the first conceptions of the theory developed in Prop. 3 of this section, were in some degree aided by the study of his researches.

The two following examples are intended to elucidate the theory of disappearing factors.

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* Vol. ii. pp. 169, 193.

Ex. 4. Given $(x^2+qx^3)\frac{d^2u}{dx^2}+((a+3)qx^2+(b-i+1)x)\frac{du}{dx}+((a+1)qx-bi)u=X$, the second member representing any function of x, and i being an integer.

The symbolical form of the above equation is

$$u+q\frac{(D+a)D}{(D+b)(D-i)}\varepsilon^{\theta}u=U, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (38.)$$

wherein $U=\{(D+b)(D-i)\}^{-1}X$ with the relation $x=\varepsilon^{\theta}$. Assume as the transformed equation,

$$v+q\frac{D+a}{D+b}\varepsilon^{\theta}v=V, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (39.)$$

then $P_1\frac{\phi(D)}{\psi(D)}=P_1\frac{D}{D-i}=D(D-1)..(D-i+1)$, wherefore

$$\left.\begin{aligned}u&=(D)(D-1)..(D-i+1)v,\\ U&=(D)(D-1)..(D-i+1)V.\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (40.)$$

Now (39.) gives

$$(D+b)\ v+q\varepsilon^{\theta}(D+a+1)v=(D+b)V,$$

$$x\frac{dv}{dx}+bv+qx(x\frac{d}{dx}+a+1)v=(D+b)V,$$

$$v=\frac{1}{x^b(1+qx)^{a-b+1}}\left\{\int dx\,x^{b-1}(1+qx)^{a-b}(D+b)V+C.\right\}. \quad . \quad . \quad . \quad (41.)$$

Now from (40.) we have

$$V=\{D(D-1)..(D-i+1)\}^{-1}U,$$

$$\therefore\ (D+b)V=\{D(D-1)..(D-i+1)\}^{-1}(D+b)U.$$

But $(D+b)U=(D-i)^{-1}X$, whence

$$(D+b)V=\{D(D-1)..(D-i)\}^{-1}X.$$

In performing the inverse operation $\{D(D-1)..(D-i+1)\}^{-1}$ we must, by the second canon, retain one arbitrary constant. We choose the one derived from the factor D. Observing then that $\{D(D-1)..(D-i)\}^{-1}=\left\{x^{i+1}\left(\frac{d}{dx}\right)^{i+1}\right\}^{-1}$, we have

$$(D+b)V=\left(\frac{d}{dx}\right)^{-(i+1)}\frac{X}{x^{i+1}}+C.$$

Hence substituting in (41.),

$$v=\frac{\int dx\left\{x^{b-1}(1+qx)^{a-b}\left(\iint..dx^{i+1}\frac{X}{x^{i+1}}+C_1\right)\right\}+C}{x^b(1+qx)^{a-b+1}},$$

$$u=x^i\left(\frac{d}{dx}\right)^i\frac{\int dx\left\{x^{b-1}(1+qx)^{a-b}\left(\iint..dx^{i+1}\frac{X}{x^{i+1}}+C_1\right)\right\}+C}{x^b(1+qx)^{a-b+1}}.$$

If $X=0$, the above gives

$$u=x^i\left(\frac{d}{dx}\right)^i\frac{C+C_1\int dx\,x^{b-1}(1+qx)^{a-b}}{x^b(1+qx)^{a-b+1}}.$$

Ex. 5. Given $(1-x^2)\frac{d^2u}{dx^2}+\left(\frac{p+1}{x}-(4n-p+1)x\right)\frac{du}{dx}-2n(2n-p)u=0.$

This equation has been discussed by Poisson*. I am, however, unacquainted with his results.

Passing to the symbolical form, we have

$$u-\frac{(\mathrm{D}+2n-2)(\mathrm{D}+2n-2-p)}{\mathrm{D}(\mathrm{D}+p)}\varepsilon^{2\theta}u=0, \quad \ldots \ldots \quad (42.)$$

which is integrable in three distinct cases.

1st. When p is an odd integer, by assuming as the transformed equation

$$v-\frac{(\mathrm{D}+2n-1-p)(\mathrm{D}+2n-2-p)}{(\mathrm{D}+p)(\mathrm{D}+p-1)}\varepsilon^{2\theta}v=0,$$

then operating by (XII.).

2nd. When n is an integer, by assuming

$$v-\frac{\mathrm{D}+2n-2-p}{\mathrm{D}+p}\varepsilon^{2\theta}v=\mathrm{V},$$

which is of the first degree.

3rd, When $2n-p$ is an even integer, by assuming

$$v-\varepsilon^{2\theta}v=\mathrm{V}.$$

An equation similar to the above, and susceptible of an interesting physical application, will be treated at length in another part of this paper.

We are now prepared to assign the general conditions of integrability of the equation $u+\phi(\mathrm{D})\varepsilon^{r\theta}u=\mathrm{U}$.

In the first place, if $\phi(\mathrm{D})$ involves factors of the form $\frac{\mathrm{D}+m}{\mathrm{D}+n}$, in which $\frac{m-n}{r}$ is an integer, they may be made to disappear as in the two last examples.

Such factors being then rejected, let the remaining factors, if any, in the numerator of $\phi(\mathrm{D})$ be $(\mathrm{D}+m_1)(\mathrm{D}+m_2)..(\mathrm{D}+m_r)$, and the remaining factors, if any, in the denominator of $\phi(\mathrm{D})$ be $(\mathrm{D}+n_1)(\mathrm{D}+n_2)...(\mathrm{D}+n_r)$. The conditions required are, that the quantities.

$$\left.\begin{array}{l}\frac{m_2-m_1+1}{r}\quad\frac{m_3-m_1+2}{r}..\frac{m_r-m_1+r-1}{r}\\[2ex] \frac{n_2-n_1+1}{r}\quad\frac{n_3-n_1+2}{r}..\frac{n_r-n_1+r-1}{r}\end{array}\right\} \quad \ldots \ldots \quad (43.)$$

shall be all integers.

For in such cases the proposed equation can, by (XIV.), be transformed into the following:

$$v+f(\mathrm{D})f(\mathrm{D}-1)..(f\mathrm{D}-r+1)\varepsilon^{r\theta}v=\mathrm{V}, \quad \ldots \ldots \quad (44.)$$

wherein $f(\mathrm{D})$ is equal to $(\mathrm{D}+m_1)$, or to $(\mathrm{D}+n_1)^{-1}$, or to $\frac{\mathrm{D}+m_1}{\mathrm{D}+n_1}$, according as the factors of $\phi(\mathrm{D})$, under consideration, are of the form $(\mathrm{D}+m_1)(\mathrm{D}+m_2)..(\mathrm{D}+m_r)$,

or $\frac{1}{(\mathrm{D}+n_1)(\mathrm{D}+n_2)..(\mathrm{D}+n_r)}$, or $\frac{(\mathrm{D}+m_1)(\mathrm{D}+m_2)..(\mathrm{D}+m_r)}{(\mathrm{D}+n_1)(\mathrm{D}+n_2)..(\mathrm{D}+n_r)}$.

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[*] Journal de l'École Polytechnique, cah. xvii. p. 614.

In each of these cases (44.) is reducible by (XII.) to a system of equations of the first degree.

If for m_1 we choose the *least* of the quantities $m_1\, m_2 \ldots m_r$, and for n_1 the *greatest* of the quantities $n_1\, n_2 \ldots n_r$, the final derivation of u from v will be effected by differentiation.

The only integrable forms of the equation $u+\varphi(\mathrm{D})\varepsilon^{r\theta}u=\mathrm{U}$, which are not comprised in the above generalisation, are those which finally depend on a transformation affecting the independent variable. They are included, so far as I have been able to ascertain, in the two following general cases, viz.

$$u+a\frac{(\mathrm{D}+m)^2\pm q^2}{(\mathrm{D}+n)(\mathrm{D}+n_1)}\varepsilon^{2\theta}u=\mathrm{U} \quad \ldots\ldots\ldots \quad (45.)$$

$$u+a\frac{(\mathrm{D}+n)(\mathrm{D}+n_1)}{(\mathrm{D}+m)^2\pm q^2}\varepsilon^{2\theta}u=\mathrm{U}, \quad \ldots\ldots\ldots \quad (46.)$$

wherein $n-m$ is an even, and n_1-m an odd integer, positive or negative.

If in (46.) we assume $\theta=-\theta'$, then multiply by $\varepsilon^{2\theta'}$, and reduce, the result will be of the general form (45.), which alone therefore it will suffice to consider.

By the successive application of Propositions 2 and 3 the equation (45.) may be reduced to the form

$$v+a\frac{(\mathrm{D}-2)^2\pm q^2}{\mathrm{D}(\mathrm{D}-1)}\varepsilon^{2\theta}v=\mathrm{V};$$

and this equation may always be integrated by putting x in the place of ε^{θ}, and then assuming $\int\frac{dx}{\sqrt{1+ax^2}}=y$, *vide* (23.). A single example will suffice.

Ex. 6. Given $(1-x^2)\frac{d^2u}{dx^2}-(2m+1)x\frac{du}{dx}-(m^2-q^2)u=0$, m being an integer.

The symbolical form is

$$u-\frac{(\mathrm{D}+m-2)^2-q^2}{\mathrm{D}(\mathrm{D}-1)}\varepsilon^{2\theta}u=0. \quad \ldots\ldots\ldots \quad (47.)$$

Let $u=\varepsilon^{-m\theta}u_1$, then by (XIII.), Prop. 2,

$$u_1-\frac{(\mathrm{D}-2)^2-q^2}{(\mathrm{D}-m)(\mathrm{D}-m-1)}\varepsilon^{2\theta}u_1=0.$$

Assume $$v-\frac{(\mathrm{D}-2)^2-q^2}{\mathrm{D}(\mathrm{D}-1)}\varepsilon^{2\theta}v=0. \quad \ldots\ldots\ldots\ldots \quad (48.)$$

Here $\mathrm{P}_2\frac{\varphi(\mathrm{D})}{\psi(\mathrm{D})}=\mathrm{P}_2\frac{\mathrm{D}(\mathrm{D}-1)}{(\mathrm{D}-m)(\mathrm{D}-m-1)}=\mathrm{D}(\mathrm{D}-1)\ldots(\mathrm{D}-m+1)$, whence

$$u_1=\mathrm{D}(\mathrm{D}-1)\ldots(\mathrm{D}-m+1)v=x^m\left(\frac{d}{dx}\right)^m v.$$

Now (48.) gives $(1-x^2)\frac{d^2v}{dx^2}-x\frac{dv}{dx}+q^2v=0$, which, integrated by the method above explained, leads to $v=c_1\cos(q\sin x^{-1})+c_2\sin(q\sin^{-1}x)$, whence finally,

$$u=\left(\frac{d}{dx}\right)^m\{c_1\cos(q\sin^{-1}x)+c_2\sin(q\sin^{-1}x)\}. \quad \ldots\ldots \quad (49.)$$

By reasoning precisely similar to that of Prop. 3, it may be shown that the equation $u+\phi_1(D)\varepsilon^{\theta}u\ldots+\phi_n(D)\varepsilon^{n\theta}u=U$ may be converted into the form $v+\psi_1(D)\varepsilon^{\theta}v\ldots.+\psi_n(D)\varepsilon^{n\theta}v=V$, by the assumptions,

$$\left.\begin{aligned} u&=P_1\frac{\phi_1(D)}{\psi_1(D)}v=P_2\frac{\phi_2(D)}{\psi_2(D)}v\ldots=P_n\frac{\phi_n(D)}{\psi_n(D)}v\ldots \\ U&=P_1\frac{\phi_1(D)}{\psi_1(D)}V\ldots=P_n\frac{\phi_n(D)}{\psi_n(D)}V. \end{aligned}\right\} \quad \ldots\ldots \quad \text{(XV.)}$$

That these assumptions may be realized, it is necessary that $\psi_1(D)$, $\psi_2(D)\,..\,\psi_n(D)$ should be so chosen as to satisfy the conditions,

$$\frac{\phi_2(D)}{\psi_2(D)}=\frac{\phi_1(D)\phi_1(D-1)}{\psi_1(D)\psi_1(D-1)},$$

$$\ldots\ldots\ldots$$

$$\frac{\phi_n(D)}{\psi_n(D)}=\frac{\phi_1(D)\phi_1(D-1)\,..\,\phi_1(D-n+1)}{\psi_1(D)\psi_1(D-1)\,..\,\psi_1(D-n+1)}.$$

These conditions being satisfied, the first of the equations (XV.), viz. $u=P_1\frac{\phi_1(D)}{\psi_1(D)}v$, will enable us to deduce u from v.

It is seldom that an application of the above theorem is necessary, and a single example on the present occasion will suffice.

Ex. 7. Given $(a+bx)\frac{d^2u}{dx^2}+(f+gx)\frac{du}{dx}+ngu=0$.

The symbolical form of this equation is

$$u+\frac{b}{a}\,\frac{D+\frac{f}{b}-2}{D}\,\varepsilon^{\theta}u+\frac{g}{a}\,\frac{D+n-2}{D(D-1)}\varepsilon^{2\theta}u=0.$$

Assume as the transformed equation,

$$v+\frac{b}{a}\,\frac{D+\frac{f}{b}-2}{D+n-1}\,\varepsilon^{\theta}v+\frac{g}{a}\,\frac{1}{D+n-1}\varepsilon^{2\theta}v=V.$$

Here we have

$$P_1\frac{\phi_1(D)}{\psi_1(D)}=P_1\frac{D+n-1}{D}=(D+n-1)(D+n-2)\,..\,(D+1),$$

$$P_2\frac{\phi_2(D)}{\psi_2(D)}=P_2\frac{(D+n-1)(D+n-2)}{D(D-1)}=(D+n-1)(D+n-2)\,..\,(D+1),$$

and these forms are identical. Hence

$$u=(D+n-1)(D+n-2)\,..\,(D+1)v=\left(\frac{d}{dx}\right)^{n-1}x^{n-1}v, \quad \ldots \quad (50.)$$

$$0=(D+n-1)(D+n-2)\,..\,(D+1)V. \quad \ldots\ldots \quad (51.)$$

As a factor of $\phi_2(D)$ has disappeared in the transformed equation, it is necessary, by the second canon, to retain an arbitrary constant in the value of V. Now the complete integral of (51.) is $V=c\varepsilon^{-\theta}+c'\varepsilon^{-2\theta}\,..\,+c''\varepsilon^{-(n-1)\theta}$, whereof we shall retain the first term in the second member. Hence

$$v+\frac{b}{a}\,\frac{\mathrm{D}+\frac{f}{b}-2}{(\mathrm{D}+n-1)}\epsilon^{\theta}v+\frac{g}{a}\,\frac{1}{\mathrm{D}+n-1}\epsilon^{2\theta}v=\mathrm{C}\epsilon^{-\theta},$$

and putting $\epsilon^{\theta}=x$ and reducing,

$$\frac{dv}{dx}+\frac{(n-1)a+(f-b)x+gx^2}{ax+bx^2}v=\frac{\mathrm{C}}{x^2(a+bx)},$$

an equation of the first degree, whence the value of v being determined, that of u is given by (50.).

The methods above developed are also applicable, *mutatis mutandis*, to partial and to simultaneous equations.

C. § 2. *Some Illustrations of a more General Method of Resolution.*

We have, in Propositions 2 and 3 of the last section, fully considered the theory of the differential equation $u+\phi(\mathrm{D})\epsilon^{r\theta}u=\mathrm{U}$, and have exhibited in Prop. 1 a method of resolution by which a more extensive class of equations may be reduced to the preceding form. In what follows I purpose to exemplify a more general method of resolution, founded on the expansion of $f(\pi+\rho)$ in (I.). This method is deserving of particular attention for two reasons; first, because, in connexion with Propositions 2 and 3 already referred to, it enables us to integrate almost every class of linear differential equations that admits of integration in finite terms; and, secondly, because a strictly analogous method is applicable to equations of finite differences.

I shall suppose the differential equation to be placed under the form

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\phi(\mathrm{D})\epsilon^{\theta}u+f_2(\mathrm{D})\phi(\mathrm{D})\phi(\mathrm{D}-1)\epsilon^{2\theta}u\ldots=\mathrm{U},$$

where $f_0(\mathrm{D})$, $f_1(\mathrm{D})$, &c. are any rational and entire functions of D, and $\phi(\mathrm{D})$ any function whatever of that symbol.

Let $\mathrm{D}-n\phi(\mathrm{D})\epsilon^{\theta}=\pi$ and $\phi(\mathrm{D})\epsilon^{\theta}=\rho$, then by reasoning precisely similar to that of A, Prop. 3, it is seen that π and ρ combine according to the law,

$$\rho f(\pi)u=f(\pi-1)\rho u.$$

Now $\phi(\mathrm{D})\epsilon^{\theta}=\rho$, $\phi(\mathrm{D})\phi(\mathrm{D}-1)\epsilon^{2\theta}=\rho^2$, and so on. Wherefore the proposed equation will assume the form

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\rho u+f_2(\mathrm{D})\rho^2u+\text{&c.}=\mathrm{U}. \quad \ldots\ldots \quad (52.)$$

But $\mathrm{D}=\pi+n\rho$, wherefore, expanding the coefficients of the above equation by (I.), we have

$$f_0(\mathrm{D})=f_0(\pi)+n\frac{\Delta}{\Delta\pi}f_0(\pi)\rho+\frac{n^2}{1.2}\frac{\Delta^2}{\Delta\pi^2}f_0(\pi)\rho^2+\text{&c.}$$

And similarly for the rest, the interpretation of $\frac{\Delta}{\Delta\pi}$ being

$$\frac{\Delta}{\Delta\pi}f(\pi)=f(\pi)-f(\pi-1).$$

Substituting the expanded forms of f_0 (D) f_1 (D) &c. in (52.), we have a result which may be thus represented:

$$\phi_0(\varpi)u+\phi_1(\varpi)\varrho u+\phi_2(\varpi)\varrho^2+\&c.=\mathrm{U}, \quad . \quad . \quad . \quad . \quad . \quad (\mathrm{XVI.})$$

$\phi_0(\varpi)$, $\phi_1(\varpi)$, &c. being rational and entire functions of ϖ. Several distinct cases may here occur, rendering the above equation either integrable, or reducible to a simple form.

1st. It may happen that by a particular determination of n the equation (XVI.) may be reduced to a single term. Suppose that it should give

$$\phi_0(\varpi)u=\mathrm{U};$$

then if $\varpi-q_1$, $\varpi-q_2$, &c. are the factors of $\phi_0(\varpi)$, we shall, by resolution, have

$$u=\mathrm{N}_1u_1+\mathrm{N}_2u_2+\mathrm{N}_3u_3+\&c.$$

$$(\varpi-q_1)u_1=\mathrm{U}$$

$$(\varpi-q_2)u_2=\mathrm{U}.$$

On replacing ϖ by its value, $\mathrm{D}-n\phi(\mathrm{D})\epsilon^{\theta}$, the above system will assume the form

$$u+\phi_1(\mathrm{D})\epsilon^{\theta}u=\mathrm{U},$$

which has already been considered.

2nd. The coefficients $\phi_0(\varpi)$, $\phi_1(\varpi)$, &c. may be constant. The equation then becomes

$$u+a_1\varrho u+a_2\varrho^2u+\&c.=\mathrm{U},$$

which has been already considered.

3rd. The equation (XVI.) may, perhaps, be reduced to consist of a pair of terms. Suppose that it should give

$$\phi_0(\varpi)u+\phi_1(\varpi)\varrho u=\mathrm{U};$$

this may be reduced to the general form

$$u+\phi(\varpi)\varrho u=\mathrm{U}.$$

As ϖ and ϱ combine according to the laws of D and ϵ^{θ}, the above equation may be treated by Prop. 2 and 3, C. § 1, and its integrable cases determined accordingly.

In illustration of the above theory, we shall investigate the principal integrable cases of the equation

$$(lx^2+mx^3+nx^4)\frac{d^2u}{dx^2}+(l'x+m'x^2+n'x^3)\frac{du}{dx}+(l''+m''x+n''x^2)u=0.$$

The symbolical form of the above equation is

$$\{l\mathrm{D}(\mathrm{D}-1)+l'\mathrm{D}+l''\}u+\{m(\mathrm{D}-1)(\mathrm{D}-2)+m'(\mathrm{D}-1)+m''\}\epsilon^{\theta}u$$
$$+\{n(\mathrm{D}-2)(\mathrm{D}-3)+n'(\mathrm{D}-2)+n''\}\epsilon^{2\theta}u=0;$$

or, as it may be written,

$$l(\mathrm{D}+\alpha)(\mathrm{D}+\beta)u+m(\mathrm{D}+\alpha')(\mathrm{D}+\beta')\epsilon^{\theta}u+n(\mathrm{D}+\alpha'')(\mathrm{D}+\beta'')\epsilon^{2\theta}u=0, \quad . \quad . \quad (53.)$$

wherein

$$\alpha=\frac{l'-l+\sqrt{(l'-l)^2-4ll''}}{2l},\qquad \beta=\frac{l'-l-\sqrt{(l'-l)^2-4ll''}}{2l},$$

$$\alpha'=\frac{m'-3m+\sqrt{(m'-m)^2-4mm''}}{2m},\quad \beta'=\frac{m'-3m-\sqrt{(m'-m)^2-4mm''}}{2m},$$

$$\alpha''=\frac{n'-5n+\sqrt{(n'-n)^2-4nn''}}{2n},\qquad \beta''=\frac{n'-5n-\sqrt{(n'-n)^2-4nn''}}{2n}.$$

It may happen that some of the factors, $D+\alpha$, $D+\beta$, &c., are wanting. This would modify the investigation. We shall, however, here suppose that they are all retained, and shall seek the conditions of integrability under this supposition.

The equation is reducible to the first order, and therefore integrable, if any of the following eight conditions is satisfied:

$$\alpha \text{ or } \beta=\alpha' \text{ or } \beta'=\alpha'' \text{ or } \beta''.$$

Thus if we have $\alpha=\alpha'=\alpha''$, we find

$$l(D+\beta)u+m(D+\beta')\varepsilon^{\theta}u+n(D+\beta'')\varepsilon^{2\theta}u=(D+\alpha)^{-1}0=c\varepsilon^{-\alpha\theta},$$

which is an equation of the first order.

Suppose that we have

$$\left.\begin{aligned}\beta'&=\alpha''=\beta''+1,\\ \alpha'&=\beta\;=\alpha\;-1.\end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad (54.)$$

The equation then becomes

$$l(D+\alpha)(D+\alpha-1)u+m(D+\alpha-1)(D+\beta')\varepsilon^{\theta}u+n(D+\beta')(D+\beta'-1)\varepsilon^{2\theta}u=0;$$

or

$$u+\frac{m}{l}\,\frac{D+\beta'}{D+\alpha}\varepsilon^{\theta}u+\frac{n}{l}\,\frac{(D+\beta')(D+\beta'-1)}{(D+\alpha)(D+\alpha-1)}\varepsilon^{2\theta}u=0,$$

which has already been integrated, Ex. to Prop. 1, C. § 1. There are several other cases in which this method of reduction will apply.

If the conditions (54.) are not both satisfied, let it be supposed that the first is satisfied, we have

$$(D+\alpha)(D+\beta)u+\frac{m}{l}(D+\alpha')(D+\beta')\varepsilon^{\theta}u+\frac{n}{l}(D+\beta')(D+\beta'-1)\varepsilon^{2\theta}u=0.$$

Put

$$(D+\beta')\varepsilon^{\theta}=\varrho,\ D=\pi+q\varrho,$$

then

$$(D+\alpha)(D+\beta)u+\frac{m}{l}(D+\alpha')\varrho u+\frac{n}{l}\varrho^2u=0.$$

Expanding the coefficients as directed in the rule, we have

$$(D+\alpha)(D+\beta)=(\pi+\alpha)(\pi+\beta)+q(2\pi+\alpha+\beta-1)\varrho+q^2\varrho^2.\quad \frac{m}{l}(D+\alpha')=\frac{m}{l}(\pi+\alpha'+q\varrho)\,;$$

the substitution of these values will give

$$(\pi+\alpha)(\pi+\beta)u+\left\{\left(2q+\frac{m}{l}\right)\pi+q(\alpha+\beta-1)+\frac{m}{l}\alpha'\right\}\varrho u+\left(q^2+\frac{m}{l}q+\frac{n}{l}\right)\varrho^2u=0;$$

or, as we may for simplicity write,

$$(\pi+\alpha)(\pi+\beta)u+(A\pi+B)\varrho u+C\varrho^2u=0,$$

wherein $$A=2q+\frac{m}{l},\quad B=q(\alpha+\beta-1)+\frac{m}{l}\alpha',\quad C=q^2+\frac{m}{l}q+\frac{n}{l}.$$

This is integrable in several distinct cases.

1st. Put $C=0$, and taking either value of q, suppose that we have $A=0$, $B=0$, then

$$(\pi+\alpha)(\pi+\beta)u=0,$$

which is reducible to a pair of equations of the first order, and is completely integrable.

2nd. Determine q so as to satisfy the equation $C=0$, then

$$(\pi+\alpha)(\pi+\beta)u+(A\pi+B)\varrho u=0,$$

or $$u+A\frac{\pi+\frac{B}{A}}{(\pi+\alpha)(\pi+\beta)}\varrho u=0.$$

This is reducible to the first order whenever $\frac{B}{A}$ differs by an integer from α or β. Thus, suppose that $\frac{B}{A}-\alpha$ is an integer, then assuming

$$v+\frac{A}{\pi+\beta}\varrho u=0,$$

we have $$u=P_1\frac{\varphi(\pi)}{\psi(\pi)}v,=P_1\frac{\pi+\frac{B}{A}}{\pi+\alpha}v,=\left(\pi+\frac{B}{A}\right)\left(\pi+\frac{B}{A}-1\right)..(\pi+\alpha+1)v.$$

The equation for determining v is of the first order, and the derivation of u from v is effected by processes which involve differentiation only.

3rd. Let $A=0$, and determining q, let $B=0$, then

$$u+\frac{C}{(\pi+\alpha)(\pi+\beta)}\varrho^2u=0.$$

Suppose α greater than β, and assume

$$v+\frac{C}{(\pi+\alpha)(\pi+\alpha-1)}\varrho^2u=0,$$

then $$u=P_2\frac{\pi+\alpha-1}{\pi+\beta}v=(\pi+\alpha-1)(\pi+\alpha-3)..(\pi+\beta+2)v.$$

Here it is necessary that α and β should differ by an integer. The equation determining v is reducible to a pair of equations of the first order, and u will be found, as in the last example, by differentiation; thus,

$$\begin{aligned}\pi v=(D-q\varrho)v&=\{D-q(D+\beta')\epsilon^{\theta'}\}v,\\&=\{D-q\epsilon^{\theta'}(D+\beta'+1)\}v,\\&=(x-qx^2)\frac{dv}{dx}-q(\beta'+1)xv.\end{aligned}$$

If in the general equation (53.) we assume $\theta=-\theta'$, and multiply by $\epsilon^{2\theta'}$, we find

$$n(D'-\alpha''-2)(D'-\beta''-2)u+m(D'-\alpha'-2)(D'-\beta'-2)\epsilon^{\theta'}u+l(D'-\alpha-2)(D'-\beta-2)\epsilon^{2\theta'}u=0.$$

Let $u=\varepsilon^{2\theta}v$, then

$$n(\mathrm{D}'-\alpha'')(\mathrm{D}-\beta'')u+m(\mathrm{D}'-\alpha')(\mathrm{D}'-\beta')\varepsilon^{\theta}u+l(\mathrm{D}'-\alpha)(\mathrm{D}'-\beta)\varepsilon^{2\theta}u=0,$$

wherein $\mathrm{D}'=\frac{d}{d\theta}$. The comparison of this equation with (53.) shows that if in the equations of condition which we have obtained, we change α into $-\alpha''$, β into $-\beta''$, l into n, and *vice versâ*, we shall obtain a new series of conditions of integrability. There are probably a few cases which the above analysis would fail to discover. Should the attention of analysts be turned to this subject, it is not unlikely that we shall soon be able to tabulate the forms of $f_0(\mathrm{D}), f_1(\mathrm{D}), f_2(\mathrm{D})$, which render integrable the equation

$$f_0(\mathrm{D})u+f_1(\mathrm{D})\varepsilon^{\theta}u+f_2(\mathrm{D})\varepsilon^{2\theta}u=\mathrm{U},$$

an object which I have endeavoured to accomplish for the case in which the first member involves only two terms.

D. *Theory of Series and of Generating Functions.*

Let $u_px^p+u_{p+1}x^{p+1}\ldots+u_tx^t$ be the proposed series, and let the law of derivation of the coefficients be

$$u_m+\varphi_1(m)u_{m-1}\ldots+\varphi_n(m)u_{m-n}=0, \quad \ldots\ldots\ldots \quad (55.)$$

a law which we shall suppose to obtain for every set of $n+1$ consecutive coefficients of the series. This condition excludes from (55.) all values of m from p to $p+n-1$, and from $t+1$ to $t+n$, *i. e.* the n first values of m in the series, and the n first values of m following those in the series, because for such values of m (55.) ceases to be a relation connecting $n+1$ consecutive coefficients of the series proposed. Now by the fundamental theorem, if $u=\Sigma u_mx^m=\Sigma u_m\varepsilon^{m\theta}$, then

$$u+\varphi_1(\mathrm{D})\varepsilon^{\theta}u\ldots+\varphi_n(\mathrm{D})\varepsilon^{n\theta}u=\Sigma\{(u_m+\varphi_1(m)u^{m-1}\ldots+\varphi_n(m)u^{m-n})\varepsilon^{m\theta}\},$$

but by (55), the expression $u_m+\varphi_1(m)u_{m-1}+$&c. vanishes except for the values of m above particularized, hence to those values alone of m is the summation in the second member to be extended. The result may be expressed in the following theorem.

If $u=\Sigma u_mx^m=\Sigma u_m\varepsilon^{m\theta}$, *and if every* $n+1$ *consecutive coefficients of the series are connected by the relation*

$$u_m+\varphi_1(m)u_{m-1}\ldots+\varphi_n(m)u_{m-n}=0,$$

then

$$u+\varphi_1(\mathrm{D})\varepsilon^{\theta}u\ldots+\varphi_n(\mathrm{D})\varepsilon^{n\theta}u=\Sigma\{(u_m+\varphi_1(m)u_{m-1}\ldots+\varphi_n(m)u_{m-n})\varepsilon^{m\theta}\}, \quad \ldots \quad (\mathrm{XVII.})$$

the summation Σ in the second member of the equation extending to the first n values of m in the original series, and to the first n values of m following those which are found in the series, every value of u_m being rejected which is not contained in the given series.

The following are particular deductions from the above theorem.

Let $u=u_px^p+u_{p+r}x^{p+r}+u_{p+2r}x^{p+2r}\ldots+u_tx^t$, and let the law of derivation of the coefficients be $u_m=\varphi(m)u_{m-r}$, then

$$u_m-\varphi(m)u_{m-r}=0, \quad \ldots\ldots\ldots\ldots \quad (56.)$$

$$u-\varphi(\mathrm{D})\varepsilon^{r\theta}u=\Sigma\{u_m-\varphi(m)u_{m-r})\varepsilon^{m\theta}\}.$$

Here the only values of m, whereof account is to be taken, are p and $t+r$. If $m=p$, we have, under the sign of summation, the expression $(u_p-\varphi(p)u_{p-r})\varepsilon^{p\theta}$, but u_{p-r} not being a coefficient of the original series is to be rejected, so that we have simply $u_p\varepsilon^{p\theta}$. Assuming $m=t+r$, we have under Σ the expression $(u_{t+r}-\varphi(t+r)u_t)$ $\varepsilon^{(t+r)\theta}$, from which u_{t+r} being rejected, leaves $-\varphi(t+r)u_t$, wherefore

$$u-\varphi(D)\varepsilon^{r\theta}u=u_p\varepsilon^{p\theta}-\varphi(t+r)u_t\varepsilon^{(t+r)\theta}.$$

Since by (56.), $u_{t+r}-\varphi(t+r)u_t=0$, the above equation may be written under the somewhat simpler form,

$$u-\varphi(D)\varepsilon^{r\theta}u=u_p\varepsilon^{p\theta}-u_{t+r}\varepsilon^{(t+r)\theta}. \quad \text{. . . . .} \quad (57.)$$

If the series is infinite,

$$u-\varphi(D)\varepsilon^{r\theta}u=u_p\varepsilon^{p\theta}. \quad \text{. . . . .} \quad (58.)$$

Let $u=u_px^p+u_{p+1}x^{p+1}+u_{p+2}x^{p+2}\ldots+u_tx^t$, and let the law of derivation of the coefficients be

$$u_m+\varphi_1(m)u_{m-1}+\varphi_2(m)u_{m-2}=0.$$

Here by the theorem,

$$u+\varphi_1(D)\varepsilon^{\theta}u+\varphi_2(D)\varepsilon^{2\theta}u=\Sigma\{(u_m+\varphi_1(m)u_{m-1}+\varphi_2(m)u_{m-2})\varepsilon^{m\theta}\},$$

the values of m to be considered being $p, p+1, t+1, t+2$.

Whence the second member gives

$$u_p\varepsilon^{p\theta}+(u_{p+1}+\varphi_1(p+1)u_p)\varepsilon^{(p+1)\theta}+(\varphi_1(t+1)u_t+\varphi_2(t+1)u_{t-1})\varepsilon^{(t+1)\theta}+\varphi_2(t+2)\varepsilon^{(t+2)\theta}.$$

This expression also may be simplified, as in the preceding case, for

$$u_{p+1}+\varphi(p+1)u_p=-\varphi_2(p+1)u_{p-1},$$
$$\varphi_1(t+1)u_t+\varphi_2(t+1)u_{t+1}=-u_{t+1}.$$

Wherefore finally,

$$u+\varphi_1(D)\varepsilon^{\theta}u+\varphi_2(D)\varepsilon^{2\theta}u=u_p\varepsilon^{p\theta}-\varphi_2(p+1)u_{p+1}\varepsilon^{(p+1)\theta}-u_{t+1}\varepsilon^{(t+1)\theta}+\varphi_2(t+2)u_t\varepsilon^{(t+2)\theta}. \quad \text{. . .} \quad (59.)$$

Ex. 1. Let $u=1-\frac{n^2}{1.2}x^2+\frac{n^2(n^2-2^2)}{1.2.3.4}x^4-\frac{n^2(n^2-2^2)(n^2-4^2)}{1.2....6}x^6+\&c.$

Here $u_m=-\frac{n^2-(m-2)^2}{m(m-1)}u_{m-2}$, wherefore by (57.),

$$u-\frac{(D-2)^2-n^2}{D(D-1)}\varepsilon^{2\theta}u=1.$$

$$(1-x^2)\frac{d^2u}{dx^2}-x\frac{du}{dx}+n^2u=0.$$

$$u=c_1\cos(n\sin^{-1}x)+c_2\sin(n\sin^{-1}x).$$

Determining the constants by comparison with the original series, we find $u=\cos(nw)$, wherein w is that value of $\sin^{-1}x$ which lies between $-\frac{\pi}{2}$ and $\frac{\pi}{2}$.

Similarly for the series $x-\frac{n^2-1^2}{1.2.3}x^3+\frac{(n^2-1^2)(n^2-3^2)}{1.2.3.4.5}x^5-\&c.$, we find $u=\frac{1}{n}\sin(nw)$. The correctness of these results will be shown by substituting Poinsot's expansions.

Ex. 2. To sum the remainder of Taylor's series, viz.

$$\frac{d^n\phi(a)}{da^n}\frac{x^n}{1.2..n}+\frac{d^{n+1}\phi(a)}{da^{n+1}}\frac{x^{n+1}}{1.2..n+1}+\ \&c.$$

Here $u_m=\frac{1}{m}\frac{d}{da}u_{m-1}$, or $u_m-\frac{1}{m}\frac{d}{du}u_{m-1}=0$, whence

$$u-(\mathrm{D})^{-1}\frac{d}{da}\epsilon^{\theta}u=\frac{d^n\phi(a)}{da^n}\,\frac{\epsilon^{n\theta}}{1.2..n},$$

$$\frac{du}{d\theta}-\frac{d}{da}\epsilon^{\theta}u=\frac{d^n\phi a}{du^n}\,\frac{\epsilon^{n\theta}}{1.2..n-1},$$

$$\frac{du}{dx}-\frac{du}{da}=\frac{d^n\phi(a)}{da^n}\,\frac{x^{n-1}}{1.2..n-1},$$

a partial differential equation of the first order, of which the complete integral is

$$u=\epsilon^{x\frac{d}{da}}\left(\int\epsilon^{-x\frac{d}{da}}\frac{d^n\phi(a)}{da^n}\,\frac{x^{n-1}dx}{1.2..n-1}+\psi(a)\right),$$

$$=\epsilon^{x\frac{d}{da}}\int\frac{x^{n-1}dx}{1.2..n-1}\,\frac{d^n}{da^n}\,\phi(a-x)+\psi(a+x),$$

ψ denoting an arbitrary function.

Now u vanishes with x whatever may be the value of a, therefore the arbitrary function and the lower limit of the integral are each 0; wherefore

$$u=\epsilon^{x\frac{d}{da}}\int_0^x dx\,\frac{x^{n-1}}{1.2..n-1}\,\frac{d^n\phi(a-x)}{da^n}, \quad \ldots\ldots\ldots\ldots \quad (60.)$$

the symbol $\epsilon^{x\frac{d}{da}}$ implying that after integration we are to change a into $a+x$.

Series of the class $f(p)x^p+f(p+r)x^{p+r}+f(p+2r)x^{p+2r}+$ &c., wherein $f(m)$ is a function of invariable form, may be reduced to linear equations with constant coefficients.

We have $u=f(p)x^p+f(p+r)x^{p+r}+$ &c. Here $u_m=f(m)$, $u_{m-r}=f(m-r)$, hence $u_m=\frac{f(m)}{f(m-r)}u_{m-r}$, or $u_m-\frac{f(m)}{f(m-r)}u_{m-r}=0$, wherefore

$$u-\frac{f(\mathrm{D})}{f(\mathrm{D}-r)}\epsilon^{r\theta}u=f(p)\epsilon^{p\theta}. \quad \ldots\ldots\ldots \quad (61.)$$

Assume $v-\epsilon^{r\theta}v=\mathrm{V}$, then $\mathrm{P}_r\frac{\phi(\mathrm{D})}{\psi(\mathrm{D})}=\mathrm{P}_r\frac{f(\mathrm{D})}{f(\mathrm{D}-r)}=f(\mathrm{D})$, whence

$$u=f(\mathrm{D})v,$$

$$f(p)\epsilon^{p\theta}=f(\mathrm{D})\mathrm{V}.$$

The last equation gives $\mathrm{V}=\epsilon^{p\theta}$, therefore $v=\frac{\epsilon^{p\theta}}{1-\epsilon^{r\theta}}$, and

$$u=f(\mathrm{D})\,\frac{\epsilon^{p\theta}}{1-\epsilon^{r\theta}}. \quad \ldots\ldots\ldots\ldots \quad (\mathrm{XVIII.})$$

This remarkable result may be otherwise obtained; thus,

$$u=\Sigma_{m=p}^{m=\infty}f(m)\epsilon^{m\theta}=\Sigma_{m=p}^{m=\infty}f(\mathrm{D})\epsilon^{m\theta},$$

$$=f(\mathrm{D})\Sigma_{m=p}^{m=\infty}\epsilon^{m\theta}=f(\mathrm{D})\,\frac{\epsilon^{p\theta}}{1-\epsilon^{r\theta}}.$$

If we wish to sum a finite portion of the development, let $f(p)x^p$ be the first term of the series as before, and $f(p')x^{p'}$ the first term of the remainder of the series, that is, of the portion following that which is to be reduced to a finite form, then

$$u=f(\mathrm{D})\frac{\varepsilon^{p\theta}-\varepsilon^{p'\theta}}{1-\varepsilon^{r\theta}}. \qquad (62.)$$

Ex. 3. Let $u=1.2..nx+2.3..(n+1)x^2+3.4..(n+2)x^3\ldots+t(t+1)\ldots(t+n-1)x^t$.
Here $f(m)=m(m+1)..(m+n-1)$, therefore

$$u=\mathrm{D}(\mathrm{D}+1)..(\mathrm{D}+n-1)\frac{\varepsilon^{\theta}-\varepsilon^{(t+1)\theta}}{1-\varepsilon^{\theta}},$$

$$=x\frac{d^n}{dx^n}x^{n-1}\frac{x-x^{t+1}}{1-x},$$

$$=x\left(\frac{d}{dx}\right)^n\frac{x^n-x^{t+n}}{1-x}.$$

Ex. 4. Let $u=1^nx+2^nx^2+3^nx^3\ldots+t^nx^t$.
Here $f(m)=m^n$, whence

$$u=\mathrm{D}^n\frac{\varepsilon^{\theta}-\varepsilon^{(t+1)\theta}}{1-\varepsilon^{\theta}}=\left(x\frac{d}{dx}\right)^n\frac{x-x^{t+1}}{1-x}.$$

Ex. 5. Let $u=1+(\cos v)x+(\cos 2v)x^2+$ &c. to t terms.
Here $f(m)=\cos(mv)$, wherefore

$$u=\cos(v\mathrm{D})\frac{1-\varepsilon^{t\theta}}{1-\varepsilon^{\theta}},$$

$$=\frac{1}{2}\left(\varepsilon^{v\mathrm{D}\sqrt{-1}}+\varepsilon^{-v\mathrm{D}\sqrt{-1}}\right)\frac{1-\varepsilon^{t\theta}}{1-\varepsilon^{\theta}},$$

$$=\frac{1}{2}\left(\frac{1-\varepsilon^{t(\theta+v\sqrt{-1})}}{1-\varepsilon^{\theta+v\sqrt{-1}}}+\frac{1-\varepsilon^{t(\theta-v\sqrt{-1})}}{1-\varepsilon^{\theta-v\sqrt{-1}}}\right),$$

$$=\frac{1-x\cos v-x^t\cos(tv)+x^{t+1}\cos(t-1)v}{1-2x\cos v+x^2}.$$

Ex. 6. Let $u=\frac{4x^3}{1.2.3}+\frac{5x^4}{2.3.4}+\frac{6x^5}{3.4.5}+$ &c., *ad inf.*

Here $f(m)=\frac{m+1}{m(m-1)(m-2)}$, whence

$$u=\frac{\mathrm{D}+1}{\mathrm{D}(\mathrm{D}-1)(\mathrm{D}-2)}\frac{\varepsilon^{3\theta}}{1-\varepsilon^{\theta}},$$

$$=\left\{\frac{1}{2}\mathrm{D}^{-1}-2(\mathrm{D}-1)^{-1}+\frac{3}{2}(\mathrm{D}-2)^{-1}\right\}\frac{\varepsilon^{3\theta}}{1-\varepsilon^{\theta}},$$

$$=\left\{\frac{1}{2}\mathrm{D}^{-1}-2\varepsilon^{\theta}\mathrm{D}^{-1}\varepsilon^{-\theta}+\frac{3}{2}\varepsilon^{2\theta}\mathrm{D}^{-1}\varepsilon^{-2\theta}\right\}\frac{\varepsilon^{3\theta}}{1-\varepsilon^{\theta}},$$

$$=\frac{1}{2}\int\frac{\varepsilon^{3\theta}d\theta}{1-\varepsilon^{\theta}}-2\varepsilon^{\theta}\int\frac{\varepsilon^{2\theta}d\theta}{1-\varepsilon^{\theta}}+\frac{3}{2}\varepsilon^{2\theta}\int\frac{\varepsilon^{\theta}d\theta}{1-\varepsilon^{\theta}},$$

$$=\frac{1}{2}\int\frac{x^2dx}{1-x}-2x\int\frac{xdx}{1-x}+\frac{3}{2}x^2\int\frac{dx}{1-x}.$$

Effecting the integrations, and determining the constants by comparison with the original series, we have

$$u=\frac{7}{4}x^2-\frac{1}{2}x-\left(\frac{1}{2}-2x+\frac{3}{2}x^2\right)\log(1-x).$$

When, as in the above case, the factors of the denominator of $f(m)$ are equidifferent, the value of a may be determined by the solution of an equation of the first order. Thus:

Ex. Let $u=\frac{f(0)}{1.2..n}+\frac{f(1)}{2.3..(n+1)}x+\frac{f(2)}{3.4..(n+2)}x^2+$ &c., *ad inf.*,

wherein $f(m)$ is of the form $a+bm+cm^2+$ &c., being finite and not involving any negative or fractional indices.

Here $$u_m=\frac{f(m)}{(m+1)(m+2)..(m+n)},\text{ whence}$$

$$u_m-\frac{f(m)}{f(m-1)}\frac{m}{m+n}u_{m-1}=0,$$

$$u-\frac{f(\mathrm{D})}{f(\mathrm{D}-1)}\frac{\mathrm{D}}{\mathrm{D}+n}\varepsilon^{\theta}u=\frac{f(0)}{1.2..n}.$$

Assume

$$v-\frac{\mathrm{D}}{\mathrm{D}+n}\varepsilon^{\theta}v=\mathrm{V},$$

we find $u=f(\mathrm{D})v$, $\frac{f(0)}{1.2..n}=f(\mathrm{D})\mathrm{V}$, whence $\mathrm{V}=\frac{1}{1.2..n}$, and substituting

$$v-\frac{\mathrm{D}}{\mathrm{D}+n}\varepsilon^{\theta}v=\frac{1}{1.2..n},$$

$$(\mathrm{D}+n)v-\varepsilon^{\theta}(\mathrm{D}+1)v=\frac{1}{1.2..(n-1)}=\frac{1}{\Gamma(n)},$$

$$v=\frac{(1-\varepsilon^{\theta})^{n-1}}{\Gamma(n)\varepsilon^{n\theta}}\int\frac{\varepsilon^{n\theta}d\theta}{(1-\varepsilon^{\theta})^n},$$

$$u=f(\mathrm{D})\frac{(1-\varepsilon^{\theta})^{n-1}}{\Gamma(n)\varepsilon^{n\theta}}\int\frac{\varepsilon^{n\theta}d\theta}{(1-\varepsilon^{\theta})^n},$$

$$=\frac{1}{\Gamma(n)}f\left(x\frac{d}{dx}\right)\frac{(1-x)^{n-1}}{x^n}\int_0^x\frac{x^{n-1}dx}{(1-x)^n},$$

a result always finite when n is an integer.

The theorem (XVIII.) may be extended to series involving any number of variables. Let $u=\Sigma f(m_1m_2..)x_1^{m_1}x_2^{m_2}..$, f being a function of invariable form, and the summation Σ extending to all positive integer values of $m_1m_2..$, then

$$u=f(\mathrm{D}_1\mathrm{D}_2..)\frac{1}{(1-\varepsilon^{\theta_1})(1-\varepsilon^{\theta_2})}..,\quad\ldots\ldots\quad(63.)$$

wherein $\varepsilon^{\theta_1}=x_1$, $\varepsilon^{\theta_2}=x_2$, &c. The performance of the operation $f(\mathrm{D}_1\mathrm{D}_2..)$ will involve differentiation, or the solution of a partial differential equation with constant coefficients.

A still more remarkable theorem is the following.

Let $u=\Sigma f(m_1 m_2 \ldots m_n) x_1^{m_1} x_2^{m_2} \ldots x_n^{m_n}$, *the summation extending to all positive integer values* (0 *included*) *of* $m_1 m_2 \ldots m_n$, *which satisfy the condition*

$$m_1+m_2\ldots+m_n=\nu,$$

then if $\varepsilon^{\theta_1}=x_1$, $\varepsilon^{\theta_2}=x_2$, &c.,

$$u=f(\mathrm{D}_1.\mathrm{D}_2\ldots\mathrm{D}_n)\{\mathrm{X}_1\varepsilon^{\nu\theta_1}+\mathrm{X}_2\varepsilon^{\nu\theta_2}\ldots+\mathrm{X}_n\varepsilon^{\nu\theta_n}\}, \quad \ldots\ldots \quad (64.)$$

wherein

$$\mathrm{X}_1=\frac{\varepsilon^{(n-1)\theta_1}}{(\varepsilon^{\theta_1}-\varepsilon^{\theta_2})(\varepsilon^{\theta_1}-\varepsilon^{\theta_3})\ldots(\varepsilon^{\theta_1}-\varepsilon^{\theta_n})},$$

$$\mathrm{X}_2=\frac{\varepsilon^{(n-1)\theta_2}}{(\varepsilon^{\theta_2}-\varepsilon^{\theta_1})(\varepsilon^{\theta_2}-\varepsilon^{\theta_3})\ldots(\varepsilon^{\theta_2}-\varepsilon^{\theta_n})},$$

and so on for the rest. What is particularly to be noticed is, that the quantities X_1, $\mathrm{X}_2 \ldots \mathrm{X}_n$ are independent of ν.

Lastly, if the condition under which the summation is to be effected is

$$m_1+m_2\ldots+m_n \overset{=}{<} \nu,$$

the rest as before, then

$$u=f(\mathrm{D}_1,\ \mathrm{D}_2\ldots\mathrm{D}_n)\left\{\mathrm{X}_1\frac{1-\varepsilon^{(\nu+1)\theta_1}}{1-\varepsilon^{\theta_1}}+\mathrm{X}_2\frac{1-\varepsilon^{(\nu+1)\theta_2}}{1-\varepsilon^{\theta_2}}+\&\text{c.}\right\}. \quad \ldots \quad (65.)$$

As an example, suppose it required to obtain a finite expression for $\Sigma(mnx^m y^n)$ subject to the condition

$$m+n=\nu.$$

Here by the theorem,

$$u=\mathrm{D}_1\mathrm{D}_2\left\{\frac{\varepsilon^{(\nu+1)\theta_1}}{\varepsilon^{\theta_1}-\varepsilon^{\theta_2}}+\frac{\varepsilon^{(\nu+1)\theta_2}}{\varepsilon^{\theta_2}-\varepsilon^{\theta_1}}\right\},$$

$$=xy\frac{d^2}{dxdy}\,\frac{x^{\nu+1}-y^{\nu+1}}{x-y},$$

$$=xy\frac{(\nu-1)(x^{\nu+1}-y^{\nu+1})+(\nu+1)(xy^{\nu}-x^{\nu}y)}{(x-y)^3}.$$

Thus let $\nu=3$, we have

$$u=xy\frac{2x^4-4x^3y+4xy^3-2y^4}{(x-y)^3},$$

$$=2x^2y+2xy^2,$$

as it evidently should be.

D. § 2. *On the Theory of Generating Functions as connected with Equations of Differences.*

The complete solution of the equation of differences

$$u_m+\phi_1(m)u_{m-1}+\phi_2(m)u_{m-2}\ldots+\phi_n(m)u_{m-n}=f(m), \quad \ldots \quad (66.)$$

involves n arbitrary constants. This implies that n successive values of u_m may be regarded as indeterminate, the remaining values being thence formed according to the law of which (66.) is the expression. The research of the generating function of u_m implies the finding of a function u, developable in a series, $\Sigma u_m x^m$, of which the first index p, and the first n coefficients u_p, $u_{p+1} \ldots u_{p+n-1}$ are arbitrary, and the remaining coefficients are formed in subjection to the law (66.).

In what follows we shall suppose that the first index p is 0, and that the n arbitrary coefficients of the development of u corresponding to the n arbitrary constants in the solution of the equation of differences, are u_0, $u_1..u_{n-1}$.

Let $f(m)=t_m$, then

$$u_m+\varphi_1(m)u_{m-1}...+\varphi_n(m)u_{m-n}-t_m=0.$$

Let also t be the generating function of t_m, as is u of u_m, so that

$$u=\Sigma_{m=0}^{m=\infty}(u_m\varepsilon^{m\theta}).t=\Sigma_{m=0}^{m=\infty}(t_m\varepsilon^{m\theta}).$$

By the fundamental theorem of development,

$$u+\varphi_1(\mathrm{D})\varepsilon^{\theta}u..+\varphi_n(\mathrm{D})\varepsilon^{n\theta}u-v=\Sigma\{(u_m+\varphi_1(m)u_{m-1}...+\varphi_n(m)u_{m-n}-t_m)\varepsilon^{m\theta}\}.$$

Now considering the expression in the second member under the sign Σ, let $m=0$, and it becomes u_0-t_0, for which as u_0 is arbitrary, we may write c_0, an arbitrary constant. Secondly, let $m=1$, we have $(u_1+\varphi_0(1)u_0-t_1)\varepsilon^{\theta}=c_1\varepsilon^{\theta}$, since u_1 is arbitrary. In like manner may we proceed till we arrive at the assumption $m=n-1$, which gives the term $c_{n-1}\varepsilon^{(n-1)\theta}$. For all values of m greater than $n-1$, the expression under Σ vanishes by (66.), wherefore

$$u+\varphi_1(\mathrm{D})\varepsilon^{\theta}u...+\varphi_n(\mathrm{D})\varepsilon^{n\theta}u-t=c_0+c_1\varepsilon^{\theta}..+c_{n-1}\varepsilon^{(n-1)\theta};$$

or replacing t by its value, and transposing to the second member,

$$u+\varphi_1(\mathrm{D})\varepsilon^{\theta}u..+\varphi_n(\mathrm{D})\varepsilon^{n\theta}u=\Sigma_{m=0}^{m=\infty}f(m)\varepsilon^{m\theta}+c_0+c_1\varepsilon^{\theta}..+c_{n-1}\varepsilon^{(n-1)\theta}. \quad . \quad . \quad (\mathrm{XIX.})$$

Ex. 1. Given $u_m+a_1\frac{m-n-1}{m}u_{m-1}+a_2\frac{m-2n-2}{m}u_{m-2}=f(m)$ to find the generating function of u_m.

Here by the theorem

$$u+a_1\frac{\mathrm{D}-n-1}{\mathrm{D}}\varepsilon^{\theta}u+a_2\frac{\mathrm{D}-2n-2}{\mathrm{D}}\varepsilon^{2\theta}u=t+c_0+c_1\varepsilon^{\theta}, \quad . \quad . \quad . \quad . \quad . \quad (67.)$$

wherein $t=\Sigma_{m=0}^{m=\infty}f(m)\varepsilon^{m\theta}$. Hence

$$\mathrm{D}u+a_1\varepsilon^{\theta}(\mathrm{D}-n)u+a_2\varepsilon^{2\theta}(\mathrm{D}-2n)u=\frac{dt}{d\theta}+c_1\varepsilon^{\theta},$$

$$\frac{du}{dx}-n\frac{a_1+2a_2x}{1+a_1x+a_2x^2}u=\frac{\frac{dt}{dx}+c_1}{1+a_1x+a_2x^2},$$

$$u=(1+a_1x+a_2x^2)^n\left\{\int\frac{\left(\frac{dt}{dx}+c_1\right)dx}{(1+a_1x+a_2x^2)^{n+1}}+c\right\}. \quad . \quad . \quad . \quad . \quad . \quad (68.)$$

The value of t will of course be found by the preceding chapter. Suppose as a particular illustration that $f(m)=\frac{1}{1.2..m}$, then $t=\varepsilon^x$, whence

$$u=(1+a_1x+a_2x^2)^n\left\{\int dx\frac{\varepsilon^x+\mathrm{C}_1}{(1+a_1x+a_2x^2)^n}+\mathrm{C}\right\}.$$

Let $f(m)=0$, and further, let $\mathrm{C}_1=0$, then

$$u=c(1+a_1x+a_2x^2)^n;$$

this value of u involving but one arbitrary constant, the coefficient of the first term only of its development will be arbitrary, and the rest will be formed in subjection to the law proposed.

Ex. 2. Let the equation be $u_m+\frac{f(m)}{f(m-1)}\frac{a_1m+b_1}{am+b}u_{m-1}+\frac{f(m)}{f(m-2)}\frac{a_2m+b_2}{am+b}u_{m-2}=\mathrm{F}(m)$.

By the theorem we have

$$u+\frac{f(\mathrm{D})}{f(\mathrm{D}-1)}\frac{a_1\mathrm{D}+b_1}{a\mathrm{D}+b}\varepsilon^{\theta}u+\frac{f(\mathrm{D})}{f(\mathrm{D}-2)}\frac{a_2\mathrm{D}+b_2}{a\mathrm{D}+b}\varepsilon^{2\theta}u=\Sigma_{m=0}^{m=\infty}\mathrm{F}(m)\varepsilon^{m\theta}+c_0+c_1\varepsilon^{\theta}.$$

Assume $$v+\frac{a_1\mathrm{D}+b_1}{a\mathrm{D}+b}\varepsilon^{\theta}v+\frac{a_2\mathrm{D}+b_2}{a\mathrm{D}+b}\varepsilon^{2\theta}v=\mathrm{V}.$$

Here $\mathrm{P}_1\frac{f(\mathrm{D})}{f(\mathrm{D}-1)}=\mathrm{P}_2\frac{f(\mathrm{D})}{f(\mathrm{D}-2)}=f(\mathrm{D})$, whence observing that $\frac{c_0}{f(0)}$, $\frac{c_1}{f(1)}$ are still arbitrary,

$$u=f(\mathrm{D})v,$$

$$v+\frac{a_1\mathrm{D}+b_1}{a\mathrm{D}+b}\varepsilon^{\theta}v+\frac{a_2\mathrm{D}+b_2}{a\mathrm{D}+b}\varepsilon^{2\theta}u=\Sigma_{m=0}^{m=\infty}\frac{\mathrm{F}(m)}{f(m)}\varepsilon^{m\theta}+c_0+c_1\varepsilon^{\theta}.$$

From the second of these equations, which is linear, and of the first order, the complete value of v will be found, whence that of u will be obtained by differentiation, or by the solution of a differential equation with constant coefficients, according as the form of $f(\mathrm{D})$ may determine.

D. § 3. *On the Theory of Generating Functions as connected with Equations of Partial Differences.*

We shall confine our observations on this subject to the case of equations involving two independent variables, the most general form of such equations being

$$\left.\begin{array}{l}\phi_0(mn)u_{m.n}\quad+\phi_1(mn)u_{m-1.n}\quad+\phi_2(mn)u_{m-2.n}\dots\\+\psi_0(mn)u_{m.n-1}+\psi_1(mn)u_{m-1.n-1}+\psi_2(mn)u_{m-2.n-1}\dots\\+\chi_0(mn)u_{m.n-2}+\chi_1(mn)u_{m-1.n-2}+\chi_2(mn)u_{m-2.n-2}\dots\end{array}\right\}=f(mn).$$

The above equation may be placed under the form

$$\Sigma\phi(mn)u_{m-r.n-r^1}=f(mn),\quad\dots\dots\dots\quad(69.)$$

the forms of $\phi(mn)$, and the value of r and r^1, being different in different terms of the equation, the greatest difference of the values of r we shall represent by i, and the greatest difference of the values of r^1 by i^1.

Let u be the generating function of u_{mn}, its development $\Sigma(u_{mn}x^my^n)$ being arranged in ascending positive powers of the variables, the lowest index of each being 0. By reasoning similar to that employed in the preceding chapter, it may be shown that the equation for determining the value of u will be

$$\begin{aligned}\Sigma\{\phi(\mathrm{D},\mathrm{D}^1,)\varepsilon^{r\theta+r'\theta'}u\}=&\Sigma\{f(mn)\varepsilon^{m\theta+n\theta'}\}\\&+\Phi_0(\varepsilon^{\theta'})+\Phi_1(\varepsilon^{\theta'})\varepsilon^{\theta}..+\Phi_{i-1}(\varepsilon^{\theta'})\varepsilon^{(i-1)\theta}\\&+\Psi_0(\varepsilon^{\theta})+\Psi_1(\varepsilon^{\theta})\varepsilon^{\theta'}..+\Psi_{i-1}(\varepsilon^{\theta})\varepsilon^{(i-1)\theta'},\quad\dots\quad(\mathrm{XX.})\end{aligned}$$

wherein $\varepsilon^{\prime}=x$, $\varepsilon^{\prime\prime}=y$. The summation Σ in the second member extends from $m=0$ to $m=\infty$, and from $n=0$ to $n=\infty$. The functions $\Phi_0(\varepsilon^{\prime\prime})$, $\Phi_0(\varepsilon^{\prime})$, &c. are in general, but not always, arbitrary and independent. Their forms are in each particular instance to be determined by the initial conditions of the problem.

Ex. 1. Let the proposed equation be $u_{m.n}-2u_{m.n-1}-2u_{m-1.n-1}=0$.

This is one of Laplace's examples. Applying the theorem, we have

$$u-2\varepsilon^{\prime\prime}u-2\varepsilon^{\prime+\prime\prime}u=\Phi_0(\varepsilon^{\prime\prime})+\Psi_0(\varepsilon^{\prime}), \quad \dots \dots \quad (70.)$$

$$u=\frac{\Phi_0(y)+\Psi_0(x)}{1-2y-2xy}. \quad \dots \dots \quad (71.)$$

To show in what way the arbitrary functions are to be determined, let it be supposed that when $y=0$, $u=f(x)$, a known function, and when $x=0$, $u=f(y)$, a known function also, then in (71.) making successively $x=0$, $y=0$, and x and y together $=0$, we have

$$\frac{\Phi_0(y)+\Psi_0(0)}{1-2y}=f_1(y), \quad \dots \dots \quad (72.)$$

$$\Phi_0(0)+\Psi_0(x)=f(x), \quad \dots \dots \quad (73.)$$

$$\Phi_0(0)+\Psi_0(0)=f(0), \quad \dots \dots \quad (74.)$$

$(72.)\times(1-2y)+(73.)-(74.)$ gives $\Phi_0(y)+\Psi_0(x)=f(x)+(1-2y)f_1(y)-f(0)$, whence

$$u=\frac{f(x)+(1-2y)f_1(y)-f(0)}{1-2y-2xy}.$$

Ex. 2. Let $u_{m.n}+a_1\frac{m}{m+1}u_{m-1.n}+a_2u_{m.n-1}+b\frac{m}{m+1}u_{m-1.n-1}=\frac{1}{1.2..m.1.2..n}$.

Here, by the theorem,

$$u+a_1\frac{\mathrm{D}}{\mathrm{D}+1}\varepsilon^{\prime}u+a_2\varepsilon^{\prime\prime}u+b\frac{\mathrm{D}}{\mathrm{D}+1}\varepsilon^{\prime+\prime\prime}u=\varepsilon^{\varepsilon^{\prime}+\varepsilon^{\prime\prime}}+\Phi(\varepsilon^{\prime\prime})+\Psi(\varepsilon^{\prime}).$$

Assume $\quad v+a_1\varepsilon^{\prime}v+a_2\varepsilon^{\prime\prime}v+b\varepsilon^{\prime+\prime\prime}v=\mathrm{V}$, then $\mathrm{P}_1\frac{\mathrm{D}}{\mathrm{D}+1}=\frac{1}{\mathrm{D}+1}$,

whence $\quad u=(\mathrm{D}+1)^{-1}v=\varepsilon^{-\prime}(\mathrm{D})^{-1}\varepsilon^{\prime}v=\frac{1}{x}\int vdx$, also $\mathrm{V}=(\mathrm{D}+1)\mathrm{U}$

$$=\left(x\frac{d}{dx}+1\right)(\varepsilon^{x+y}+\Phi(y)+\Psi(x))=(x+1)\varepsilon^{x+y}+\mathrm{F}(x)+\mathrm{F}_1(y),$$

the functions $\mathrm{F}(x)$ and $\mathrm{F}_1(y)$ being arbitrary. Hence the equation determining v becomes

$$v+a_1xv+a_2yv+bxyv=(x+1)\varepsilon^{x+y}+\mathrm{F}(x)+\mathrm{F}_1(y),$$

$$\therefore \quad v=\frac{(x+1)\varepsilon^{x+y}+\mathrm{F}(x)+\mathrm{F}_1(y)}{1+a_1x+a_2y+bxy},$$

$$u=\frac{1}{x}\int dx\frac{(x+1)\varepsilon^{x+y}+\mathrm{F}(x)+\mathrm{F}_1(y)}{1+a_1x+a_2y+bxy}. \quad \dots \dots \quad (75.)$$

Had the second member of the original equation been 0, we should have had

$$u=\frac{1}{x}\int dx\frac{\mathrm{F}(x)+\mathrm{F}_1(y)}{1+a_1x+a_2y+bxy}. \quad \dots \dots \quad (76.)$$

Suppose it here, as before, required to determine the arbitrary functions by the conditions that $x=0$, $y=0$ shall respectively give $u=f(x)$, and $u=f_1(y)$; differentiating (76.) and proceeding as before, we find

$$u=\frac{1}{x}\int dx\frac{(1+a_1x)\left(x\frac{d}{dx}+1\right)f(x)+(1+a_2y)f_1(y)-f(0)}{1+a_1x+a_2y+bxy}.$$

The general theorem (XX.) applied in the two preceding examples is formed on the condition that the generating function u shall involve in its development positive powers only of x and y. This condition introduces into the second member a greater number of arbitrary functions than would otherwise be necessary. If, for example, it were merely required that the indices of y in the development should be positive and ascending, the form of the second member of (XX.) would simply be

$$\Sigma f(mn)\varepsilon^{m\theta+n\theta'}+\psi_0(\varepsilon^{\theta})+\psi_1(\varepsilon^{\theta})\varepsilon^{\theta'}..+\psi_{i'-1}(\varepsilon^{\theta})\varepsilon^{\theta'}.$$

Which of the two assumptions is preferable or necessary must be determined by special considerations.

As an example of the latter form, let us take the very simple equation

$$m(m-1)u_{m.n-2}-a^2n(n-1)u_{m-2.n}=0.$$

We have

$$D(D-1)\varepsilon^{2\theta'}u-a^2D'(D'-1)\varepsilon^{2\theta}u=F_0(\varepsilon^{\theta})+F_1(\varepsilon^{\theta})\varepsilon^{\theta'},$$

$$\therefore\ \frac{d^2u}{dx^2}-a^2\frac{d^2u}{dy^2}=\frac{F_0(x)+F_1(x)y}{x^2y^2}.$$

The solution of this equation will put us in possession of the complete value of u, the functions $F_0(x)$, $F_1(x)$ admitting of either positive or negative indices in their developments. If we assume those functions to vanish, we get

$$u=\phi(y+ax)+\psi(y-ax),$$

which is a particular value of the generating function.

Many other developments and applications might be here given, were the subject of sufficient importance to justify further detail.

E. *Application of the Theory of Series to the Evaluation of certain Definite Integrals.*

Ex. 1. The function $(1-2\nu\cos\omega+\nu^2)^{-n}$ being expanded in a series of the form

$$A_0+2(A_1\cos\omega+A_2\cos 2\omega+A_3\cos 3\omega+\text{\&c.}),$$

it is required to determine the general coefficient A_r.

We have

$$(1-2\nu\cos\omega+\nu^2)^{-n}=(1-\nu\varepsilon^{\omega\sqrt{-1}})^{-n}\times(1-\nu\varepsilon^{-\omega\sqrt{-1}})^{-n},$$

$$=\left(1+n\nu\varepsilon^{\omega\sqrt{-1}}+\frac{n(n+1)}{1.2}\nu^2\varepsilon^{2\omega\sqrt{-1}}+\frac{n(n+1)(n+2)}{1.2.3}\nu^3\varepsilon^{3\omega\sqrt{-1}}+\text{\&c.}\right)$$

$$\times\left(1+n\nu\varepsilon^{-\omega\sqrt{-1}}+\frac{n(n+1)}{1.2}\nu^2\varepsilon^{-2\omega\sqrt{-1}}+\frac{n(n+1)(n+2)}{1.2.3}\nu^3\varepsilon^{-3\omega\sqrt{-1}}+\text{\&c.}\right),$$

and the quantity sought, A_r, will be the common coefficient of $\varepsilon^{r\omega\sqrt{-1}}$ and $\varepsilon^{-r\omega\sqrt{-1}}$ in the above product. Hence

$$\mathrm{A}_r = 1 \times \frac{n(n+1)..(n+r-1)}{1.2..r}\nu^r + \frac{n}{1} \times \frac{n(n+1)..(n+r)}{1.2..r+1}\nu^{r+2}$$

$$+\frac{n(n+1}{1.2} \times \frac{n(n+1)..(n+r+1)}{1.2..r+2}\nu^{r+4} + \&\text{c. } \textit{ad infinitum}.$$

Put $\nu^2 = t$, then

$$\mathrm{A}_r = t^{\frac{r}{2}} \Sigma_{m=0}^{m=\infty} (u_m t^m), \quad \ldots\ldots\ldots\ldots \quad (77.)$$

wherein generally $u_m = \dfrac{n(n+1)..(n+m-1)}{1.2..m} \times \dfrac{n(n+1)..(n+r+m-1)}{1.2..(r+m)}$,

the law of derivation being

$$u_m - \frac{(n+m-1)(n+r+m-1)}{m(m+r)} u_{m-1} = 0.$$

Hence, if $\Sigma u_m t^m = u$, and if $t = \epsilon^{\theta}$, then

$$u - \frac{(\mathrm{D}+n-1)(\mathrm{D}+r+n-1)}{\mathrm{D}(\mathrm{D}+r)} \epsilon^{\theta} u = \frac{n(n+1)..(n+r-1)}{1.2..r} = \mathrm{U}. \quad \ldots\ldots \quad (78.)$$

To integrate this equation, assume

$$v - \epsilon^{\theta} v = \mathrm{V}.$$

Then $\quad u = \mathrm{P}_1 \dfrac{(\mathrm{D}+n-1)(\mathrm{D}+r+n-1)}{\mathrm{D}(\mathrm{D}+r)} v,$

$$= (\mathrm{D}+n-1)(\mathrm{D}+n-2)..(\mathrm{D}+1).(\mathrm{D}+r+n-1)..(\mathrm{D}+r+1)v,$$

$$\mathrm{U} = (\mathrm{D}+n-1)(\mathrm{D}+n-2)..(\mathrm{D}+1).(\mathrm{D}+r+n-1)..(\mathrm{D}+r+1)\mathrm{V}.$$

Hence determining V, we have

$$v - \epsilon^{\theta} v = \frac{n(n+1)..(n+r-1)}{1.2..r} \times \frac{1}{1.2..(n-1).(r+1)(r+2)..(r+n-1)},$$

$$= \frac{1}{\{1.2..(n-1)\}^2} = \frac{1}{\{\Gamma(n)\}^2},$$

$$\therefore \quad v = \frac{1}{\{\Gamma(n)\}^2(1-\epsilon^{\theta})}.$$

Now $\quad u = (\mathrm{D}+r+n-1)..(\mathrm{D}+r+1).(\mathrm{D}+n-1)..(\mathrm{D}+1)v,$

but $\quad (\mathrm{D}+r+n-1)..(\mathrm{D}+r+1) = t^{-r}\left(\dfrac{d}{dt}\right)^{n-1} t^{r+n-1},$

and $\quad (\mathrm{D}+n-1)..(\mathrm{D}+1) = \left(\dfrac{d}{dt}\right)^{n-1} t^{n-1},$

hence $\quad u = t^{-r}\left(\dfrac{d}{dt}\right)^{n-1} t^{r+n-1}\left(\dfrac{d}{dt}\right)^{n-1} \dfrac{t^{n-1}}{\{\Gamma(n)\}^2(1-t)}.$

But $\quad \left(\dfrac{d}{dt}\right)^{n-1} \dfrac{t^{n-1}}{1-t} = \left(\dfrac{d}{dt}\right)^{n-1} \dfrac{1}{1-t}$ (this may be shown by expansion)

$$= \frac{1.2..n-1}{(1-t)^n} = \frac{\Gamma(n)}{(1-t)^n},$$

therefore $$u=t^{-r}\left(\frac{d}{dt}\right)^{n-1}\frac{t^{r+n-1}}{\Gamma(n)(1-t)^{n}},$$

and $$\mathrm{A}_r=\frac{1}{\Gamma(n)t^{\frac{r}{2}}}\left(\frac{d}{dt}\right)^{n-1}\frac{t^{r+n-1}}{(1-t)^{n}} \quad \ldots\ldots\ldots\ldots \quad (79.)$$

wherein $t=\nu^2$, a formula of great simplicity.

Hence then we find

$$\int_0^{\pi}\frac{dx\cos rx}{(1-2\nu\cos x+\nu^2)^n}=\frac{\pi}{\Gamma(n)t^{\frac{r}{2}}}\left(\frac{d}{dt}\right)^{n-1}\frac{t^{r+n-1}}{(1-t)^{n}}. \quad \ldots\ldots\ldots \quad (80.)$$

Legendre has, I believe, considered the above definite integral, but I am not acquainted with the results of his analysis.

The following expression for the value V of the definite integral

$$\int_0^{\pi}\frac{dx\cos rx}{(1-2\nu_1\cos x+\nu_1^{2})^{l}(1-2\nu_2\cos x+\nu_2^{2})^{m}\ldots\varrho\text{ factors}}$$

is remarkable for its symmetry,

$$\mathrm{V}=\frac{\pi}{\Gamma(l)\Gamma(m)\ldots}\left(\frac{d}{dt_1}\right)^{l-1}\left(\frac{d}{dt_2}\right)^{m-1}\frac{t_1^{\,l-1}t_2^{\,m-1}\ldots}{\ldots(1-t_1)^{l}(1-t_2)^{m}\ldots}\left\{\mathrm{T}_1\left(\frac{t_1}{\nu_1}\right)^{r+\varrho-1}+\mathrm{T}_2\left(\frac{t_2}{\nu^2}\right)^{r+\varrho-1}+\&\text{c.}\right\} \quad (81.)$$

wherein, after effecting the differentiations, we must change t_1 into ν_1^2, t_2 into ν_2^2, &c., observing that

$$\mathrm{T}_1=\frac{\left\{1-\left(\frac{t_2}{\nu_2}\right)^2\right\}\left\{1-\left(\frac{t_3}{\nu_3}\right)^2\right\}\ldots\left\{1-\left(\frac{t_\varrho}{\nu_\varrho}\right)^2\right\}}{\left(\frac{t_1}{\nu_1}-\frac{t_2}{\nu_2}\right)\left(\frac{t_1}{\nu_1}-\frac{t_3}{\nu_3}\right)\ldots\left(\frac{t_1}{\nu_1}-\frac{t_\varrho}{\nu_\varrho}\right)};$$

and so on for the rest.

Ex. 2. To express by a partial differential equation the fundamental properties of the definite multiple integral

$$u=\iint\ldots dx_1dx_2\ldots dx_n\varphi(a_1-x_1,\ a_2-x_2\ldots a_n-x_n) \quad \ldots\ldots \quad (82.)$$

the integrations extending to all real values of $x_1x_2\ldots x_n$, subject to the inequality

$$\frac{x_1^2}{h_1^2}+\frac{x_2^2}{h_2^2}\ldots+\frac{x_n^2}{h_n^2}\leqq 1.$$

We may consider the above integral as derived from the more general one,

$$u=\iint\ldots dx_1dx_2\ldots dx_n\varphi(a_1-x_1t,\ a_2-x_2t\ldots a_n-x_nt),$$

by the assumption $t=1$. If we expand $\varphi(a_1-x_1t,\ a_2-x_2t\ldots a_n-x_nt)$ in ascending powers of t, and integrate within the proposed limits by the aid of Dirichlet's theorem, we find

$$u=\frac{2h_1h_2\ldots h_n\pi^{\frac{n}{2}}}{\Gamma\left(\frac{n}{2}\right)}\Sigma_{p=0}^{p=\infty}\frac{1}{2\,4\ldots 2p.n(n+2)\ldots(n+2p)}\lambda^{2p}t^{2p}\varphi(a_1a_2\ldots a_n), \quad \ldots \quad (83.)$$

wherein $$\lambda^2=h_1^{\,2}\frac{d^2}{da_1^{\,2}}+h_2^{\,2}\frac{d^2}{da_2^{\,2}}+h_n^{\,2}\frac{d^2}{da_n^{\,2}}\text{*}.$$

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* Cambridge Mathematical Journal, No. XIV. p. 69.

If we write the above series in the form $u=\Sigma u_m t^m$, then it is easily seen that

$$u_m-\frac{1}{m(m+n)}\lambda^2 u_{m-2}=0.$$

Hence, if $t=\varepsilon^\theta$,

$$u-\frac{\lambda^2}{\mathrm{D}(\mathrm{D}+n)}\varepsilon^{2\theta}u=\frac{2h_1h_2..h_n\pi^{\frac{n}{2}}}{n\Gamma\left(\frac{n}{2}\right)}, \quad \text{. . . . .} \quad (84.)$$

$$\therefore \quad \mathrm{D}(\mathrm{D}+n)u-\lambda^2\varepsilon^{2\theta}u=0.$$

Restoring t, and for λ^2 writing

$$h_1{}^2\frac{d^2}{da_1{}^2}+h_2{}^2\frac{d^2}{da_2{}^2}..+h_n{}^2\frac{d^2}{da_n{}^2},$$

and then dividing the result by t^2, we have

$$\frac{d^2u}{dt^2}+\frac{n+1}{t}\frac{du}{dt}-h_1{}^2\frac{d^2u}{da_1{}^2}-h_2{}^2\frac{d^2u}{da_2{}^2}\cdots-h_n{}^2\frac{d^2u}{da_n{}^2}=0, \quad \text{. . . . . .} \quad (85.)$$

which is the equation sought.

Mr. Green*, considering a particular case of this multiple integral connected with the theory of the attractions of ellipsoids, has obtained an equation different from the above, and not involving the constants $h_1h_2..h_n$. It might be worth while to inquire whether the equation (85.) does not more precisely define the function to be determined than Mr. Green's equation does, and whether an analysis might not be founded upon it which should be more simple, and less dependent on foreign considerations. It would too much extend the limits of this paper to enter into the general discussion of the equation here, and I shall therefore merely observe that it is reducible whenever n is an odd integer, to the form

$$\frac{d^2u}{dt^2}-h_1{}^2\frac{d^2u}{da_1{}^2}-h_2{}^2\frac{d^2u}{da_2{}^2}-\cdots-h_n{}^2\frac{d^2u}{da_n{}^2}=0. \quad \text{. . . . . . .} \quad (86.)$$

To prove this, we remark that the constant in the second member of (84.) may be rejected, because in operating on both members with $\mathrm{D}(\mathrm{D}+n)$ it disappears. Writing then the equation in the form

$$u-\frac{\lambda^2}{\mathrm{D}(\mathrm{D}+n)}\varepsilon^{2\theta}u=0,$$

let us assume

$$v-\frac{\lambda^2}{\mathrm{D}(\mathrm{D}-1)}\varepsilon^{2\theta}v=0. \quad \text{. . . . .} \quad (87.)$$

By Propositions 2 and 3, C. § 1, we find

$$u=\varepsilon^{-n\theta}(\mathrm{D}-1)(\mathrm{D}-3)..(\mathrm{D}-n+2)v$$
$$=\frac{1}{t^n}\left(t\frac{d}{dt}-1\right)\left(t\frac{d}{dt}-3\right)..\left(t\frac{d}{dt}-n+2\right)v.$$

Then in (87.) making $\varepsilon^\theta=t$, we have

$$\frac{d^2v}{dt^2}-\lambda^2v=0,$$

which is equivalent to (86.)

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* Cambridge Philosophical Transactions, vol. v.

Ex. 3. *To evaluate the definite multiple integral*

$$\mathrm{V}=\iint..\frac{dx_1dx_2..dx_n}{\{(a_1-x_1)^2+(a_2-x_2)^2..+(a_n-x_n)^2\}^i}, \quad \ldots\ldots \quad (88.)$$

n *being an odd integer,* i *any quantity whatever, positive or negative, integral or fractional, and the integrations extending to all real values of the variables, subject to the condition*

$$x_1^2+x_2^2..+x_n^2 \overline{\overline{<}} 1.$$

Here $\phi(a_1a_2..a_n)=\frac{1}{(a_1^2+a_2^2..+a_n^2)^i}$. By induction it is easily shown* that

$$\left(\frac{d^2}{da_1^2}+\frac{d^2}{da_2^2}...+\frac{d^2}{da_n^2}\right)^p\frac{1}{(a_1^2+a_2^2...+a_n^2)^i}=\frac{2i(2i+2)...(2i+2p-2)(2i+2-n)(2i+4-n)..(2i+2p-n)}{(a_1^2+a_2^2..+a_n^2)^{i+p}}.$$

Hence the series (83.) becomes on making $(a_1^2+a_2^2..+a_n^2)^{\frac{1}{2}}=r$,

$$\mathrm{V}=\frac{2\pi^{\frac{n}{2}}}{\Gamma\left(\frac{n}{2}\right)r^{2i}}\Sigma_{p=0}^{p=\infty}\frac{2i..(2i+2p-2)(2i+2-n)..(2i+2p-n)}{2.4..2pn(n+2)..(n+2p)}r^{-2p}, \; =\frac{2\pi}{\Gamma\left(\frac{n}{2}\right)r^{2i}}\Sigma_{p=0}^{p=\infty}u_{-2p}r^{-2p},$$

the law of the series being $u_{-2p}=\frac{(2p+2)(2p+n+2)}{(2p+2i)(2p+2i-n+2)}u_{-2p-2}$;

or putting $-2p=m$, $\quad u_m-\frac{(m-2)(m-n-2)}{(m-2i)(m-2i+n-2)}u_{m-2}=0.$

And as the series extends to all the values of u_m which can be formed in subjection to the law, we have

$$u-\frac{(\mathrm{D}-2)(\mathrm{D}-n-2)}{(\mathrm{D}-2i)(\mathrm{D}-2i+n-2)}\epsilon^{2\theta}u=0. \quad \ldots\ldots \quad (89.)$$

To integrate this equation, assume

$$v-\frac{(\mathrm{D}-n-1)(\mathrm{D}-n-2)}{(\mathrm{D}-2i+n-2)(\mathrm{D}-2i+n-3)}\epsilon^{2\theta}v=0. \quad \ldots\ldots \quad (90.)$$

Then by (XIV.)

$$u=\mathrm{P}_2\frac{(\mathrm{D}-2)(\mathrm{D}-2i+n-3)}{(\mathrm{D}-n-1)(\mathrm{D}-2i)}v,$$
$$=(\mathrm{D}-2)..(\mathrm{D}-n+1)(\mathrm{D}-2i+n-3)..(\mathrm{D}-2i+2)v,$$
$$=(\mathrm{D}-2)^{\frac{n-1}{2}/2}(\mathrm{D}-2i+n-3)^{\frac{n-3}{2}/2}v,$$

wherein the index $\frac{n-1}{2}/2$ denotes the product of $\frac{n-1}{2}$ factors, decreasing by a common difference 2.

The equation (90.), treated by the method of Prop. 1, C. § 1, gives

$$v=\frac{1}{2}(v_1+v_2)$$

$$v_1+\frac{\mathrm{D}-n-1}{\mathrm{D}-2i+n-2}\epsilon^{\theta}v_1=0, \quad v_2-\frac{\mathrm{D}-n-1}{\mathrm{D}-2i+n-2}\epsilon^{\theta}v_2=0.$$

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* Cambridge Mathematical Journal, No. XIV. p. 63.

Whence determining v_1 and v_2,

$$v=\frac{C_1(\epsilon^{\theta}+1)^{2n-2i-2}+C_2(\epsilon^{\theta}-1)^{2n-2i-2}}{\epsilon^{(n-2i-2)\theta}}. \quad \dots\dots \quad (91.)$$

If we substitute this value of v in that of u, determining the constants C_1 and C_2 by expansion and comparison with the original series, and effect some obvious reductions, we finally get*

$$V=\frac{2\pi^{\frac{n-1}{2}}}{r^{n-2}}\,\frac{\left(r\frac{d}{dr}+2i-n\right)^{\frac{n-1}{2}|2}\left(r\frac{d}{dr}-1\right)^{\frac{n-3}{2}|2}}{\left(2i-n+1\right)^{n|1}\left(i-1\right)^{\frac{n-3}{2}|1}}\{(r+1)^{2n-2i-2}-(r-1)^{2n-2i-2}\}. \quad . \; . \; . \quad (92.)$$

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* This example is given merely for the sake of the process. The fullest development of the theory of definite multiple integrals will be found in the writings of M. Lejeune Dirichlet and Mr. Cayley. Some results, believed to be new, are subjoined.

1. If $u=\iint..dx_1dx_2..dx_n\phi(a_1-x_1,\ a_2-x_2..a_n-x_n)$ subject to the inequality $\frac{x_1^2}{h_1^2}+\frac{x_2^2}{h_2^2}..+\frac{x_n^2}{h_n^2}\leqq t^2$, then

$$u-\frac{\lambda^2}{D(D-n)}\epsilon^{2\theta}u=0, \quad \dots\dots\dots\dots \quad (a.)$$

where $\lambda^2=h_1^2\frac{d^2}{da_1^2}+h_2^2\frac{d^2}{da_2^2}..+h_n^2\frac{d^2}{da_n^2}$, and $\epsilon^{\theta}=t$. This is a better form of the theorem in Ex. 2.

2. Let $u=\iint..dx_1dx_2..dx_nf(\Delta)$ in which $\Delta=\{(a_1-x_1)^2..+(a_n-x_n)^2\}^{\frac{1}{2}}$ subject to the inequality $x_1^2..+x_n^2 \leqq t^2$, and let $(a_1^2..+a_n^2)^{\frac{1}{2}}=r$; it is evident that u is a function of t and r. Now

$$\left(\frac{d^2}{da_1^2}..+\frac{d^2}{da_n^2}\right)\phi(r)=\left(\frac{d^2}{dr^2}+\frac{n-1}{r}\frac{d}{dr}\right)\phi(r)=\epsilon^{-2\theta'}D'(D'+n-2)\phi(\epsilon^{\theta'})\text{ if }\epsilon^{\theta'}=r.$$

Thus (*a.*) may be put in the form

$$\frac{1}{D'(D'+n-2)}\epsilon^{2\theta'}u-\frac{1}{D(D+n)}\epsilon^{2\theta}u=0;$$

the complete integral of which, determined by Propositions 2 and 3, is

$$u=\frac{1}{r^{n-2}}\left(t\frac{d}{dt}-1\right)\left(t\frac{d}{dt}-3\right)..\left(t\frac{d}{dt}-n+2\right).\left(r\frac{d}{dr}-1\right)..\left(r\frac{d}{dr}-n+4\right)\left\{\phi(r+t)+\psi(r-t)\right\}.$$

In the case of $n=3$, we find on determining the arbitrary functions

$$u=\frac{2\pi}{r}\left(t\frac{d}{dt}-1\right)\{\phi(r+t)-\phi(r-t)\},$$

wherein $\phi(r)=\iiint rf(r)dr^3$. A similar analysis is applicable to the theory of the attractions of spheroids.

3. The evaluation of the definite integral $\int_0^{\pi}dx\,(\sin x)^nf(r+t\cos x)$ depends on a partial differential equation similar to the above. Its value is

$$u=2.4..(n-1)\left(t\frac{d}{dt}-1\right)\left(t\frac{d}{dt}-3\right)..\left(t\frac{d}{dt}-n+2\right)\left(\frac{d}{dr}\right)^{-n}\{f(r+t)-f(r-t)\}.$$

4. The evaluation of the definite multiple integral $\iint..dx_1..dx_nf(a_1x_1..+a_nx_n)\phi(x_1..+x_n)$ extending to the positive limits of the inequality $x_1...+x_n\leqq h$, depends on a partial differential equation of the first order; the result is

$$u=\Sigma\frac{a_1^{n-1}}{(a_1-a_2)(a_1-a_3)..(a_1-a_n)}\int_0^h dt\phi(t)\left(\frac{d}{dt}\right)^{-n+1}f(a_1t).$$

A particular case of this theorem has been obtained by Mr. Leslie Ellis, by means of Fourier's theorem.

5. By a reverse application of the method we are able to assign the complete integral of the equation

$$\frac{d^2u}{dt^2}-h_1^2\frac{d^2u}{da_1^2}\cdots-h_n^2\frac{d^2u}{da_n^2}=0,\text{ viz.}$$

F. § 1. *Theory of Equations of Finite Differences.*

If we assume $\pi=\frac{x(\epsilon^{r\frac{d}{dx}}-1)}{r}$, $\rho=x\epsilon^{r\frac{d}{dx}}$, then it is shown (A. § 1.) that the following relations are satisfied:

$$f(\pi)\rho^m u=\rho^m f(\pi+m)u, \quad \dots \quad (93.)$$

$$f(\pi)\rho^m=f(m)\rho^m, \quad \dots \quad (94.)$$

and that

$$f(\pi+\rho)=f(\pi)+\frac{\Delta}{\Delta\pi}f(\pi)\rho+\frac{\Delta^2}{\Delta\pi^2}f(\pi)\frac{\rho^2}{1.2}+\text{\&c.}, \quad \dots \quad (95.)$$

the interpretation of $\frac{\Delta}{\Delta\pi}$ here being $\frac{\Delta}{\Delta\pi}f(\pi)=f(\pi)-f(\pi-1)$.

If $r=-1$, we have $\pi=x-x\epsilon^{-\frac{d}{dx}}$, $\rho=x\epsilon^{-\frac{d}{dx}}$, and the above relations are still satisfied. These values of π and ρ we shall first employ.

Prop. 1. *Every equation in finite differences of the form*

$$X_0u_x+X_1u_{x-1}\dots+X_nu_{x-n}=X,$$

$X_0X_1X_2$ &c. being rational and integral functions of x, may be reduced to the form

$$f_0(\pi)u_x+f_1(\pi)\rho u_x+f_2(\pi)\rho^2u_x+\text{\&c.}=U_x. \quad \dots \quad (96.)$$

For multiply both sides of the equation by $x(x-1)..(x-n+1)$, and in the second term of the first member for xu_{x-1} write ρu_x in the third term for $x(x-1)u_{x-2}$ write ρ^2u_x, &c., we shall have a result of the form

$$\phi_0(x)u_x+\phi_1(x)\rho u_x+\phi_2(x)\rho^2u_x..+\phi_n(x)\rho^nu_x=U_x, \quad \dots \quad (97.)$$

wherein $\phi_0(x)=x(x-1)..(x-n+1)X_0$, $\phi_1(x)=(x-1)..(x-n+1)X_1,\dots$ $U_x=x(x-1)..(x-n+1)X$, being all rational and integral functions of x. Now $\pi=x\left(1-\epsilon^{-\frac{d}{dx}}\right)$, $\rho=x\epsilon^{-\frac{d}{dx}}$, whence $x=\pi+\rho$. It only remains then to develope $\phi_0(x)$, $\phi_1(x)$, &c. in ascending powers of ρ. Writing then x for $\pi+\rho$ in the first member of (95.), we have

$$f(x)=f(\pi)+\frac{\Delta}{\Delta\pi}f(\pi)\rho+\frac{1}{1.2}\frac{\Delta^2}{\Delta\pi^2}f(\pi)\rho^2+\text{\&c.}, \quad \dots \quad (98.)$$

the interpretation of $\frac{\Delta}{\Delta\pi}$ remaining as above.

$$u=\frac{1}{t^{n-1}}t\frac{d}{dt}\left(t\frac{d}{dt}-2\right)..\left(t\frac{d}{dt}-n+3\right)\iint..dx_1..dx_n\phi(a_1-x_1,\ a_2-x_2..a_n-x_n),$$

$$+\frac{d}{dt}\left\{\frac{1}{t^{n-1}}t\frac{d}{dt}\left(t\frac{d}{dt}-2\right)..\left(t\frac{d}{dt}-n+3\right)\iint..dx_1..dx_n\psi(a_1-x_1,\ a_2-x_2..a_n-x_n)\right\};$$

the limits being given by the inequality

$$\frac{x_1^2}{h_1^2}+\frac{x_2^2}{h_2^2}..+\frac{x_n^2}{h_n^2}\overset{=}{<}t^2.$$

This solution requires that n should be odd. If $n=3$, the result is equivalent to POISSON's, but is in a form perhaps more convenient for physical deductions.

Developing by this theorem the coefficients of (97.), the result will assume the form

$$f_0(\pi)u_x+f_1(\pi)\varrho u_x+f_2(\pi)\varrho^2u_x+\text{ \&c.}=\mathrm{U}_x, \quad . \quad . \quad . \quad . \quad . \quad (\text{XXI.})$$

as was proposed to be shown. We shall call this the symbolical form of the equation.

To revert from the symbolical to the common form, it is only necessary to observe that since $\pi=x-\varrho$, and since x and ϱ combine according to the law $\varrho xu_x=(x-1)\varrho u_x$, we have

$$f(\pi)=f(x)-\frac{\Delta}{\Delta x}f(x)\varrho+\frac{\Delta^2}{\Delta x^2}f(x)\frac{\varrho^2}{1.2}-\text{ \&c.}, \quad . \quad . \quad . \quad . \quad (\text{XXII.})$$

wherein $\Delta x=-1$, and consequently $\frac{\Delta}{\Delta x}f(x)=f(x)-f(x-1)$. Developing by this theorem the coefficients, and writing for $\varrho^m u_x$ its value $x(x-1)..(x-m+1)u_{x-m}$, the required reversion will be effected.

F. § 2. *On the Solution of Equations of Finite Differences in Series.*

In the equation $\quad f_0(\pi)u_x+f_1(\pi)\varrho u_x\ldots+f_r(\pi)\varrho^r u_x=0,$

assume $u_x=\Sigma u_m\varrho^m$ then precisely as in the case of differential equations,

$$f_0(m)u_m+f_1(m)u_{m-1}\ldots+f_r(m)u_{m-r}=0. \quad . \quad . \quad . \quad . \quad (\text{XXIII.})$$

The initial values of m are determined by the equation $f_0(m)=0$. For every such value u_m is an arbitrary constant, for all other values it is successively determined by (XXIII.)

Ex. 1. Given $(x-a)u_x-(2x-a-1)u_{x-1}+(1-q^2)(x-1)u_{x-2}=0.$

The operation at length stands thus:

Multiply by x, we have

$$x(x-a)u_x-(2x-a-1)xu_{x-1}+(1-q^2)x(x-1)u_{x-2}=0. \quad . \quad . \quad . \quad (99.)$$

Or $\quad x(x-a)u_x-(2x-a-1)\varrho u_x+(1-q^2)\varrho^2u_x=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad (100.)$

Now developing the coefficients by (98.), we find

$$x(x-a)=\pi(\pi-a)+(2\pi-a-1)\varrho+\varrho^2,$$

$$2x-a-1=2\pi-a-1+2\varrho,$$

whence substituting in (100.)

$$\pi(\pi-a)u_x-q^2\varrho^2u_x=0,$$

wherefore $u=\Sigma a_m\varrho^m$, with the relation

$$m(m-a)a_m-q^2a_{m-2}=0,$$

$$\text{or} \quad a_m=\frac{q^2a_{m-2}}{m(m-a)}.$$

The equation $m(m-a)=0$ gives 0 and a for the lowest values of m, wherefore, finally,

$$u_x=\mathrm{C}\left(1+\frac{q^2x(x-1)}{2.2-a}+\frac{q^4x(x-1)(x-2)(x-3)}{2.4(2-a)(4-a)}+\text{\&c.}\ldots\right),$$

$$+\mathrm{C}_1\left(x(x-1)..(x-a+1)+\frac{q^2x(x-1)..(x-a-1)}{2(2+a)}+\frac{q^4x(x-1)..(x-a-3)}{2.4(2+a)(4+a)}+\text{\&c.}\right).$$

We have here two distinct series. Either of these is an integral of the equation (99.), but I apprehend that the second series only can be regarded as an integral of the original equation. The first series appears to have reference only to the irrelevant factor x. As I am not aware that this distinction has been before observed, and as it appears to affect the validity of the canon which assigns to the integral of an equation of differences just so many arbitrary constants as there are units in the index of its order, I shall make no apology for adducing another illustration.

Let us take the equation

$$xu_x=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (101.)$$

We find as the symbolical form,

$$(\pi+\rho)u_x=0;$$

whence $u_x=\Sigma a_m\rho^m$ with the relation $ma_m+a_{m-1}=0$, or $a_m=-\frac{a_{m-1}}{m}$, the lowest value of m being 0, whence

$$\begin{aligned}u_x&=C\left(1-\frac{x}{1}+\frac{x(x-1)}{1.2}-\frac{x(x-1)(x-2)}{1.2.3}+\&c.\right),\\&=C(1-1)^x,\\&=C0^x.\end{aligned}$$

This is obviously a true integral of (101.) for all values of x from 0 to ∞; for when $x=0$ it gives $u_x=C$, and when x is any positive quantity, $u_x=0$, precisely as it ought to do. Moreover it involves an arbitrary constant C; but (101.) being of the 0th order, there should, according to the received canon, be no arbitrary constant in its integral.

For the solution of the equation $x(x-1)u_x=0$, we similarly find

$$u_x=a_0+a_1x+a_2x(x-1)+a_3x(x-1)(x-2)+\&c.,$$

wherein a_0, a_1 are arbitrary constants, and in general

$$a_m=-\frac{2(m-1)a_{m-1}+a_{m-2}}{m(m-1)},$$

this gives

$$u_x=a_0+a_1x-\frac{2a_1+a_0}{2}x(x-1)+\frac{3a_1-2a_0}{6}x(x-1)(x-2)-\&c.$$

For the values $x=0$, $x=1$, the above series is reduced to an arbitrary constant; for all other positive values of x it vanishes. Here then we obtain for an equation of the 0th degree, a solution involving two arbitrary constants, and derived from the two irrelevant factors x and $x-1$.

It would be interesting to inquire whether an equation of differences admits of integration by series when $f_0(m)$ has equal or imaginary factors. After paying some attention to this question, I am disposed to think that such cases are not comprehended in any theory analogous to that which I have given for the corresponding class of differential equations.

On the subject of this section the reader may consult a paper by Mr. Bronwin in the Cambridge Mathematical Journal, vol. iii.

F. § 3. *On the Solution of Equations of Differences in Finite Terms.*

We have in the preceding section supposed $\pi = x - x\epsilon^{-\frac{d}{dx}}$, $\rho = x\epsilon^{-\frac{d}{dx}}$, and have thus satisfied the relations (93.), (94.). We shall, in the following section, with greater generality assume (A. Prop. 3.),

$$\pi = x - n\phi(x)\epsilon^{-\frac{d}{dx}}, \quad \rho = \varphi(x)\epsilon^{-\frac{d}{dx}}.$$

The condition (93.) will still be satisfied, and the expansion of $f(\pi+\rho)$ will remain unchanged.

We shall suppose the equation to be placed, as in all ordinary cases it may, under the form

$$f_0(x)u_x + f_1(x)\varphi(x)u_{x-1} + f_2(x)\varphi(x)\varphi(x-1)u_{x-2} + \&c. = \text{U}, \quad . \quad . \quad . \quad (102)$$

$f_0(x)$, $f_1(x)$, &c. being rational and integral functions of x, or at least susceptible of expansion in ascending powers of x, and $\varphi(x)$ any function whatever.

Since $\varphi(x)\epsilon^{-\frac{d}{dx}} = \rho$, we have $\varphi(x)\varphi(x-1)\epsilon^{-2\frac{d}{dx}} = \rho^2$, and so on; wherefore, writing u for u_x, we have

$$f_0(x)u + f_1(x)\rho u + f_2(x)\rho^2 u + \&c. = \text{U}.$$

Now since $\pi = x - n\rho$, we have $x = \pi + n\rho$, and expanding the coefficients $f_0(x) f_1(x)$, &c. by (I.), the equation will assume the form

$$\varphi_0(\pi)u + \varphi_1(\pi)\rho u + \varphi_2(\pi)\rho^2 u + \&c. = \text{U}. \quad . \quad . \quad . \quad . \quad . \quad (\text{XXIV.})$$

This equation is integrable in several cases:

1st. If by any determination of n the equation should be reducible to a single term. Suppose that it should give

$$\varphi_0(\pi)u = \text{U}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (103.)$$

then resolving $\varphi_0(\pi)$ into its factors, we shall have a system of equations each being of the form

$$(\pi - a)u = \text{U};$$

or

$$(x-a)u_x - n\varphi(x)u_{x-1} = \text{U},$$

which is completely integrable.

This method enables us to integrate all equations of the form (102.), in which

$$f_m(x) = \frac{h}{m}(f_{m-1}(x) - f_{m-1}(x-1)), \quad . \quad . \quad . \quad . \quad . \quad . \quad (104.)$$

h being any constant. We should find $n = -h$, $\pi = x + h\varphi(x)\epsilon^{-\frac{d}{dx}}$, and $f_0(\pi)u = \text{U}$. I am not aware that this general class of equations has been considered before. A method of integrating equations of the form

$$x(x-1)..(x-n+1)\Delta^n u_{x-n} + a_1 x(x-1)..(x-n+2)\Delta^{n-1}u_{x-n+1} + \&c. = 0,$$

was communicated to me by Mr. GREGORY*. In reality however they constitute a particular case of the above, the value of π being $x - x\epsilon^{-\frac{d}{dx}}$.

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* Late Fellow of Trinity College, Cambridge, and author of the well-known "Examples." Few in so short a life have done so much for science. The high sense which I entertain of his merits as a mathematician, is mingled with feelings of gratitude for much valuable assistance rendered to me in my earlier essays.

2nd. If the coefficients $\phi_0(\pi)$, $\phi_1(\pi)$, &c. are constant quantities. This happens in the well-known class of equations

$$u_x+a_1\phi(x)u_{x-1}+a_2\phi(x)\phi(x-1)u_{x-2}+\&c.=\mathrm{U},$$

which becomes

$$(1+a_1\rho+a_2\rho^2+\&c.)u_x=\mathrm{U},$$

and is integrable by resolution of the operating factor, as in equations with constant coefficients. It may be worth while to note that this class of equations, when of the nth degree, involves one arbitrary function $\phi(x)$, and n arbitrary constants, $a_1..a_n$; but the preceding class under the same circumstances involves one arbitrary function with $n+1$ arbitrary constants, viz. h with n constants in $f_0(x)$. It is therefore the more general of the two.

3rd. If the equation should consist of only two terms. Suppose that it should be reducible to the form

$$\phi_0(\pi)u+\phi_1(\pi)\rho^n u=\mathrm{U},$$

which may be put under the form

$$u+\phi(\pi)\rho^n u=\mathrm{U}_1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (105.)$$

Proceeding as in the corresponding case of C. § 2, it may in all cases be determined whether the equation is integrable or not.

In general the equation $u+\phi(\pi)\rho^n u=\mathrm{U}$ can be reduced to the form $v+\psi(\pi)\rho^n v=\mathrm{V}$ by the relations

$$u=\mathrm{P}_n\frac{\phi(\pi)}{\psi(\pi)}v, \quad \mathrm{U}=\mathrm{P}_n\frac{\phi(\pi)}{\psi(\pi)}\mathrm{V}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (106.)$$

precisely as in differential equations.

Thus, to pursue the analogy, the equation

$$u+\frac{q^n}{(\pi+a_1)(\pi+a_2)\ldots(\pi+a_n)}\rho^n u=\mathrm{U},$$

in which $a_1a_2..a_n$ are in the order of magnitude, can be reduced to the form

$$v+\frac{q^n}{\pi(\pi-1)..(\pi-n+1)}\rho^n v=\mathrm{V},$$

and then integrated by resolution into a system of equations of the first order, provided that the quantities

$$\frac{a_1-a_2-1}{n}, \quad \frac{a_1-a_3-2}{n}, \quad \frac{a_1-a_4-3}{n}, \quad \frac{a_1-a_n-n+1}{n}$$

are all integers.

Ex. Given $(x^2+ax+b)u_x+(2x-a-1)h\phi(x)u_{x-1}+(h^2-q^2)\phi(x)\phi(x-1)u_{x-2}=0.$

Let $\pi=x-n\phi(x)\varepsilon^{-\frac{d}{dx}}$, $\rho=\phi(x)\varepsilon^{-\frac{d}{dx}}$, then

$$(x^2+ax+b)u+(2x-a-1)h\rho u+(h^2-q^2)\rho^2 u=0.$$

Now $x=\pi+n\rho$, therefore

$$x^2+ax+b=\pi^2+a\pi+b+(2\pi-a-1)n\rho+n^2\rho^2,$$

$$2x-a-1=2\pi-a-1+2n\rho,$$

and substituting, we have

$$(\pi^2+a\pi+b)u+(2\pi-a-1)(n+h)\varrho u+(n^2+2nh+h^2-q^2)\varrho^2 u=0.$$

To take away the second term, let $n=-h$, then

$$(\pi^2+a\pi+b)u-q^2\varrho^2 u=0.$$

Let $\pi+a_1$, $\pi+a_2$ be the factors of $\pi^2+a\pi+b$, then

$$u-\frac{q^2}{(\pi+a_1)(\pi+a_2)}\varrho^2 u=0.$$

To integrate this equation, assume

$$v-\frac{q^2}{(\pi+a_1)(\pi+a_1-1)}\varrho^2 v=0, \quad . \; . \; . \; . \; . \; . \; . \; . \quad (107.)$$

then $$u=\mathrm{P}_2\frac{\pi+a_1-1}{\pi+a_2}v=(\pi+a_1-1)(\pi+a_1-3)\,..\,(\pi+a_2+2)v,$$

which is only finite when a_1-a_2 is an odd integer.

From (107.) we have

$$v=\frac{1}{2}(s_x+t_x),$$

$$s_x-\frac{q}{\pi+a_1}\varrho s_x=0,$$

$$t_x+\frac{q}{\pi+a_1}\varrho t_x=0;$$

from the first of which equations,

$$(\pi+a_1)s_x-q\varrho s_x=0,$$

$$\therefore \qquad \left(x+h\varphi(x)\varepsilon^{-\frac{d}{dx}}\right)s_x+a_1 s_x-q\varphi(x)\varepsilon^{-\frac{d}{dx}}s_x=0.$$

Or $$(x+a_1)s_x+(h-q)\varphi(x)s^{x-1}=0,$$

$$\therefore \qquad s_x=\mathrm{C}_1\mathrm{P}\frac{(q-h)\varphi(x)}{x+a_1},$$

$$=\mathrm{C}_1(q-h)^x\mathrm{P}\frac{\varphi(x)}{x+a_1}.$$

In like manner,

$$t_x=\mathrm{C}_2(q+h)^x\mathrm{P}\frac{\varphi(x)}{x+a_1};$$

and as the constants C_1, C_2 are arbitrary,

$$v=\{\mathrm{C}_1(q-h)^x+\mathrm{C}_2(q+h)^x\}\mathrm{P}\frac{\varphi(x)}{x+a_1},$$

$$u=(\pi+a_1-1)(\pi+a_1-3)\,..\,(\pi+a_2+2)\{\mathrm{C}_1(q-h)^x+\mathrm{C}_2(q+h)^x\}\mathrm{P}\frac{\varphi(x)}{x+a_1},$$

to interpret which we have only to observe that

$$\pi f(x)=xf(x)+h\varphi(x)f(x-1).$$

This solution may be put under the form

$$u=\{\mathrm{P}\phi(x)\}(\pi_1+a_1-1)(\pi_1+a_1-3)\,..\,(\pi_1+a_2+2)\left\{\frac{\mathrm{C}_1(q-h)^x+\mathrm{C}_2(q+h)^x}{\mathrm{P}(x+a_1)}\right\},$$

the interpretation of π_1 being

$$\pi_1 f(x)=xf(x)+hf(x-1).$$

The method of this section will, I believe, be found to succeed in every known integrable case, while it includes some unknown before, one of which is the most general yet discovered.

POSTSCRIPT.

The general rule for the integration of linear differential equations in series, B. § 2, requires in a particular case to be slightly modified. If $f_0(\mathrm{D})$ involves a pair of factors such as $\phi(\mathrm{D})$, $\phi(\mathrm{D}+r)$, r being a multiple of the common difference of the values of m, we must in the equation of $f_0(\mathrm{D})u=0$ write $\{\phi(\mathrm{D})\}^2$ in place of $\phi(\mathrm{D})\phi(\mathrm{D}+r)$, and similarly when there are more such factors. Thus, in the equation $\mathrm{D}(\mathrm{D}+2)u-q^2\epsilon^{2\theta}u=0$, the form of the assumption for u will be determined by the equation $\mathrm{D}^2u=0$, and not by $\mathrm{D}(\mathrm{D}+r)u=0$. A slight change of expression would make the rule as general as the principle on which it is founded, and reduce to its dominion every case in which a linear differential equation can be integrated by ascending or descending developments. The theory of series infinite in both directions still remains to be examined.

Fearful of extending this paper beyond its due limits, I have abstained from introducing any researches not essential to the development of that general method in analysis which it was proposed to exhibit. It may however be remarked that the principles on which the method is founded have a much wider range. They may be applied to the solution of functional equations, to the theory of expansions, and, to a certain extent, to the integration of non-linear differential equations. The position which I am most anxious to establish is, that any great advance in the higher analysis must be sought for by an increased attention to the laws of the combinations of symbols. The value of this principle can scarcely be overrated; and I only regret that in the absence of books, and under circumstances unfavourable for mathematical investigation, I have not been able to do that justice to it in this essay which its importance demands.

Lincoln, August 31, 1844.

IX. *On the Reproduction of lost parts in Myriapoda and Insecta.*

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THE reproduction of parts of the body that have been accidentally lost or removed, is an occurrence of so much interest, in relation to the laws of nutrition and development, that I am induced to trespass on the attention of the Royal Society with an account of some experiments on this subject in the Myriapoda and Insecta. It has long been known to every naturalist that the Crustacea and Arachnida are capable of reproducing their limbs; and it has also been stated that a similar reproduction of parts takes place in some of those insects which are active throughout their whole life, and do not change their form, but merely cast their tegument and increase in size. But it has been questioned whether any reproduction of lost parts can take place in those insects which undergo a complete metamorphosis, and change their form, their food and mode of life in passing from the young to the adult state. No investigations have hitherto been undertaken to decide the question in insects that undergo these changes, nor have any experiments been made to show that a reproduction of lost parts is common also to the whole of the Class Myriapoda.

At a meeting of the Entomological Society in November 1839*, I exhibited a specimen of *Scolopendra sub-spinipes*, which had the eleventh leg, on the left side of the body, so much smaller than the corresponding one on the right, although otherwise perfect in regard to the number of its articulations, that I regarded it as a marked instance of reproduction of the limbs in that class. As no experiments had then been made to prove the fact, this opinion was disputed, and the instance pointed out was considered as merely one of an arrest of development†. Since then it has been shown‡, as first noticed by MÜLLER§, that a reproduction of the legs most certainly takes place in the *Phasmidæ*; but it is still doubted whether it can occur in the Lepidoptera, and other tribes that undergo a complete change.

In the summer of 1841, and also in 1842, I made a series of experiments on this subject, on the Myriapoda; and during the present summer have completed a similar series on Lepidopterous insects, the results of which I have now the honour to communicate to the Royal Society.

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* Transactions of the Entomological Society of London, vol. iii. part 1. p. 33.

† Idem. Journal of Proceedings, Nov. 2, 1840, p. 14.

‡ Id. January 1, 1844. President's Address, 1844, p. 5.

§ Elements of Physiology, Dr. BALY's translation, Edit. 1. 1837, p. 405.

Myriapoda.

The facts already ascertained respecting the periodical development of new segments to the body in this class, led me to anticipate a favourable result in experimenting on the reproduction of the antennæ and legs. In the spring of 1841, I had placed about thirty nearly full-grown individuals of *Iulis terrestris* and *Iulis niger* in a closed vessel filled with clay and mould. Many of these individuals deposited ova, some of which I succeeded in rearing.

During the time these Iuli were confined together, I found several of them deprived of one of the antennæ, and also of some of the legs, which I attributed to their attacks on each other. This circumstance led me further to believe that these organs when lost are reproduced. In order to put this conclusion to the test, I cut off one of the antennæ and some of the legs of an individual that had not yet attained to more than two-thirds of the adult size of the species, and confined it in company with others of the same age. A few weeks afterwards all the specimens had changed their skins and grown much larger, having also gained an addition of segments to the body; but the antennæ and legs of the mutilated specimen had been so completely reproduced, that I could not identify the individual that had been the subject of the experiment. As, in consequence of this, the experiment was not entirely satisfactory, although it sufficiently proved to me that reproduction had actually taken place, I cut off one of the antennæ, and some of the legs, from each of three specimens that had much nearer approached their adult state. These were confined together in the same vessel, and were nearly of the same age. After watching them closely for about three months, without discovering any signs of regeneration of the lost parts, I began to fear that there must have been some error in my previous observations. However, I allowed them to remain undisturbed during the whole of the spring and commencement of summer, giving them constantly a fresh supply of food, the decaying inner bark of trees.

They continued in this state until the middle of June, when the whole of them entered the earth, and each made for itself a little circular cavity, in which it lay coiled up in a spiral form, and passed into a state of what has been designated summer hybernation, and remained until the end of July. This I found is the usual habit of the species, and did not depend on the mutilations, as during the same period I discovered many Iuli similarly concealed in the earth in their native haunts: many individuals die at this period in their estivatories, but these appear to have arrived at their full maturity, and become aged, having already deposited their ova in the spring. Those which are not yet matured now cast their teguments, and have their lost parts reproduced. The casting of the skin is a difficult and tedious occurrence. For several days after it has taken place the Iuli are unable to venture forth from their cells, but remain coiled up until their new covering has acquired strength and consolidation. When the specimens that had been deprived of their antennæ again made their appearance, I found that the experiment had been entirely successful. Each individual now had its antenna and legs reproduced; but the new parts were much shorter and smaller, and of a more delicate colour, than the uninjured corresponding parts in the same animal. The new antenna was but little more than one-half the length of the original one, and was very rarely used for touching and exploring objects, but seemed to be carefully preserved by the animal from coming into contact with anything. In two of the individuals the new organ had but six joints (Plate XIV. figs. 1 and 2.), but in these instances nearly the whole organ had been reproduced, having been cut off close to the basal joint (*a*). In the other instance the new antenna had seven joints, like the original one, but in this case the antenna had been divided, and reproduction commenced in the middle of the third basal joint (fig. 3. *b*). The joints of the new antennæ were much thicker in proportion to their length than in the perfect organ. They were thickest at each extremity, each joint resembling a figure of eight, or an elongated hour-glass. The apical joint of the antenna was very minute, and sunk into the preceding one. Each joint was encircled with hairs at its distal extremity, while the joints of the original antennæ had only a few scattered hairs on their under surface. In addition to this, the articulations of the new joints were less perfect than in the old, the intussusceptions or reduplications of the tegument forming the articulations being exceedingly slight.

There was one circumstance in connexion with these reproductions that seems especially worthy of notice. In the antenna (fig. 3.) that had been divided in the middle of the third basal joint, the junction of the new with the original part of the organ was clearly indicated by a marked difference of colour in the two portions of that joint, in which the reproduction commenced. Thus it was not the whole organ that was reproduced, in this instance, but only so many joints of it as were deficient,—part of the third, the fourth, fifth, sixth and seventh. It does not appear necessary, therefore, that, when one part has been lost, the entire organ must be removed before reproduction can take place, as is believed to be the case with the limbs of Crustacea; but reparation begins in the part in which the injury occurs, and the new structures produced are only sufficient to replace those which have been removed. In the other two instances of reproduction of the antennæ, the reparation commenced at the articulation of the first basal joint with the second (fig. 1. *a*), the basal joint of the original organ being left attached to the head in each experiment. In these two instances, as already stated, there were only six joints to the new antennæ. This deficiency I am inclined to attribute to the circumstance that the individuals had very nearly approached the time when the power of reproducing parts of their own bodies had greatly decreased, and would soon altogether cease, as was shown in the circumstance, that they had so nearly reached their adult state, that each acquired only one new segment to its body at this change of tegument, the next change of which would perhaps have been the last.

It is thus proved that the legs and antennæ of the Iulidæ are reproduced at the change of skin. Since making these experiments, I have met with many instances in which these parts have been reproduced, as indicated by comparison with corresponding parts in the same animals. In no instance has the fact been better exemplified in the Iulidæ than in a specimen of *Spirostreptus microsticticus*[*], Newp., from the coast of Africa, now in the cabinets of the British Museum, in which most of the legs on the left side of five segments of the body, from the thirty-ninth to the forty-third, have been reproduced, while the animal was living in its natural haunts. In most of these the entire limbs, including their basilar or coxal joints, have been restored, each limb being perfect in all its joints, even including the terminal claw, although not more than one-half the size of the corresponding limb on the opposite side of the same segment. From these facts, it appears that the reproduction of a lost part in the Iulidæ may take place either in connexion with some portion of the original organ, or may be entirely independent of it, as when every portion of the original organ is removed.

The reproduction of lost parts in the Chilopoda differs a little from that of the Chilognatha. Although I do not intend on the present occasion to give a detailed account of the changes and growth of animals of this order, I may state that the *Lithobii* differ a little from the Iulidæ in the mode of development of their segments and legs. Like the Iulidæ they change their tegument in the young state very frequently, and at each change, two pairs of legs, which have previously made their appearance at the sides of the new segments as very minute projecting appendages, are elongated and assume the structure and function of legs. The young Lithobius very frequently loses some of its limbs, probably from being attacked by others of its carnivorous species, as frequently occurs when several of these are kept together in confinement.

It was a specimen of *Lithobius vulgaris*, Newp. that had previously acquired its tenth pair of legs, but had very recently suffered the loss of the eighth, ninth, and tenth pairs of those organs, that formed the subject of this part of my investigations. At this period of its life the little animal is very delicate, but active, and endowed with all the ferocious habits of the adult. It was now scarcely more than one quarter of an inch in length. I had feared that at this early period the young Myriapod might not be able to support so much injury, and be able to reproduce so many pairs of lost organs. But it moved about with the remaining seven pairs of legs with its usual activity, as if in an uninjured state, and did not appear to be at all inconvenienced by its loss; but it carefully avoided coming in contact with others of its own species that were confined with it in the same phial. On this account I removed it to another phial, in order to watch its progress more accurately. Each of the legs that were lost had been removed at the articulation of the femur with the coxal joint, and from the enlarged condition of the latter part I at once suspected that new limbs were about to be produced.

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[*] List of the Specimens of Myriapoda in the Collection of the British Museum, by John Edward Gray, printed by order of the Trustees, 1844, p. 14.

On the 10th of September 1842, a few days after the commencement of my observations on this individual, the young Lithobius changed its skin, and, to my great satisfaction, not only developed two additional pairs of legs, but also reproduced three other pairs in the place of those that had been lost. Thus three pairs of organs were developed at this change, besides those which make their appearance in the usual course of growth. These three pairs of reproduced legs made their appearance at the sides of the segments, without having previously been developed in a more rudimentary form, as is always the case with the legs of Lithobius when first produced. But they were exceedingly delicate, and were much smaller than the others. They gradually increased in size, and continued to grow for a short time after the casting of the skin. The two pairs of additional legs developed at this change, and now constituting the eleventh and twelfth pairs of the body, were at first larger than the reproduced ones, and continued to grow until the next change. On the 15th of September the three pairs of reproduced legs seemed to have attained their maximum of development until the next casting of the skin, but they were not so large by one-third as the legs immediately anterior to them.

On the 24th of October the young Lithobius again lost one of its legs. This was the twelfth one on the left side that had been developed at the preceding change. Nothing further took place, either in this individual or in others of the same age, with twelve pairs of legs, until the 7th of November, when it again changed its skin, and acquired three additional pairs of legs,—thus completing the adult number, fifteen. At this time it was nearly half an inch in length. I now found not only that the first reproduced legs had very nearly attained their proper size, but also that a new leg had been developed in the place of the one that was lost on the 24th of October, but this was very much smaller than the others. The two posterior pairs of legs, at this period, were scarcely so long as those immediately anterior to them, were applied very closely together, and were entirely useless. They continued to grow in length and size, and gradually acquired a power of motion. On the 18th of November the posterior segments and legs in the young animal had nearly attained their relative proportions. On the 30th of November the posterior legs were widely separated from each other, and were occasionally employed by the animal in its retrograde movements. In this condition it remained till the end of January, having passed the interval in a state of partial hybernation. It did not again change its skin until the middle of April. During this interval the posterior pairs of legs continued to be elongated, and the reproduced legs, acquired at the two preceding castings of the tegument, were also enlarged, but still continued smaller than the others. I attributed this in part to the animal not having been supplied with a sufficiency of food. On the morning of the 22nd of May it again changed its skin, and the reproduced legs had now acquired their full size. On the

3rd of August it underwent another change of covering, after which no difference could be perceived in the size of the reproduced and of the original legs. At this time my observations were discontinued.

These facts sufficiently show that a power of reproducing lost parts is quite common to the Lithobii, and the frequent occurrence of legs that have not their full size, in specimens of foreign *Scolopendræ*, lead to the conclusion that it is equally common to those animals. There are many instances of this in the collection in the British Museum, in the majority of which it is one of the posterior legs that has been reproduced. From the number of specimens I have met with in which this is the case, I have been enabled to arrive at the conclusion, that although reproduced limbs in these animals may ultimately attain the full size of the normal structures, they never acquire a perfectly normal development of all their parts, which are sometimes supernumerary, but more frequently are deficient in number, and are almost invariably atrophied. This is strikingly illustrated in the development of the spines with which the basal joints of the posterior legs of the Scolopendræ are armed. This fact is of consequence in a zoological point of view; as these parts have recently been much depended on in the determination of species. It is also, perhaps, of some value in relation to the laws of development, since it is found to be equally constant, as I shall presently show, in the reproduced parts of the true Insecta.

Insecta.

Some experiments formerly made by Dr. HEINEKE* on the Blattæ, have already shown that these insects, which do not undergo any metamorphosis but a change of tegument, have a power of reproducing the antennæ in their young state. But no experiments were made by that naturalist to prove that the legs also are capable of being reproduced. Professor MÜLLER†, however, first showed that the *Phasmidæ*, which likewise undergo no transformation, can reproduce their legs, when lost at an early period. This has recently been fully confirmed by Mr. FORTNUM, in the *Diura violescens*, GRAY, of Australia, as communicated by letter to the Rev. F. W. HOPE‡. I may also remark, that I have recently found a specimen of Phasma in the cabinets of the British Museum, in which the right anterior leg has been reproduced, in a large species (fig. 4.), *Alopus cocophages*, GRAY, MSS., an insect from Navigator's Island, destructive to the young buds of cocoa-nut trees. This instance affords a striking exemplification of the usually incomplete development of reproduced organs. Not only is the whole limb in this specimen much shorter than the corresponding one on the opposite side, but its third tarsal joint is absent, and the other joints are imperfectly formed.

In order to ascertain whether reproduction of the limbs can take place in insects that undergo a complete metamorphosis in form, in habit, and mode of life, I have instituted a series of experiments on the larvæ of the common Nettle Butterfly, *Vanessa urticæ*.

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* Zoological Journal, vol. iv. p. 422.

† *Loc. cit.* p. 405.

‡ Proceedings of the Entomological Society of London, January 1, 1844.

On the 24th of May, in the present summer, I removed with the scissors two of the true legs of the caterpillar, on the left side of the body, from each of twelve specimens that had not yet passed into their last stage as larvæ, but were still in their *fourth* period. These legs were either entirely removed at their base, close to the body, or in the tibial or femoral joints. On the following morning I removed the intermediate, or the posterior leg, on the left side, from each of sixteen other specimens which had already entered their last larva skin, or *fifth* period. Six of these were nearly full-grown, and would have entered their pupa state in the course of a few days. The remaining ten had only recently entered their last skin. The whole of these twenty-eight larvæ were confined together in a glass vessel, and well supplied with food. Some of the specimens seemed to be but little affected by the operation, as they immediately began to feed very actively; but on the following morning several of them had died from its results. In the whole of those which had the legs removed at the base the hæmorrhage was at first very considerable; but in those which had the limb removed at the tibial joint it was not so profuse. In the specimens in which the limb was removed at the tibio-tarsal joint the hæmorrhage soon ceased, but in those in which the wound was more serious, it was less readily suppressed. But even the individuals that were most injured began to feed with avidity immediately after the operation, notwithstanding the excessive hæmorrhage that was going on. One of these specimens had not only lost the whole of its meso-thoracic leg, but was also punctured on the back, and from both wounds the green transparent circulatory fluid flowed in large quantity; but the insect still continued to feed very eagerly. In less than half an hour I had the satisfaction to find that a coagulation of the effused blood was taking place over the wounds, although at each contortion of the body the fluid gushed forth afresh. In three quarters of an hour the blood had become somewhat more firmly coagulated, and formed a dark black patch, or eschar, over the injured parts. In this way, by a coagulation of the effused fluid, the hæmorrhage from wounds in insects is first arrested. The rapidity with which this coagulation takes place seems to depend greatly on the temperature and comparative dryness of the atmosphere; since if the air of the locality in which the insect is confined be loaded with moisture, the hæmorrhage continues for a long time, and the individuals often die, as was the case with some of my first series. It was in consequence of not being aware of this, at the commencement of my experiments, that a greater number of specimens died than would otherwise have been lost from the operations. On the fourth day only twenty-two were still living; but this great mortality was clearly attributable to the cause I have stated. At the expiration of nine days, one of the six larvæ that were nearly full-grown when the experiments were commenced, changed to a chrysalis. At that time only seventeen specimens remained out of the original twenty-eight. Those which died were chiefly the youngest ones. By the thirteenth day, June 5th, the remaining specimens of the same brood had also entered the pupa state, leaving only five out of the twelve individuals first operated on, which had not then entered the last state of larvæ, still surviving the operation. By the 9th of June, the seventeenth day after the operation, these also had changed to chrysalids. It was thus evident that a removal of the limbs does not necessarily prevent the insect from undergoing its natural transformations.

During the growth of these specimens there were several circumstances that appeared well worthy of notice. It soon became evident that even in those instances in which the insects survived the operation their development was considerably retarded by it. This was shown by comparing the length of time that elapsed in their different states, with that required by other specimens of the same age, that had not undergone any operation before they changed to chrysalids,—the circumstances, in regard to age, quantity and quality of food, temperature, and locality in which they were placed, being in all exactly the same. In every instance the uninjured specimens prepared themselves for transformation very much earlier than those experimented on; and they also passed much quicker into the state of pupæ. Thus, while uninjured specimens, which had not cast their last larva skin, all underwent their changes on the 29th and morning of the 30th of May, those of the same age that had been first subjected to experiment did not undergo a corresponding change of skin until late on the 31st. Precisely the same thing occurred with the more matured larvæ, all of which were retarded in their change to the pupa state beyond the time at which others of the same age entered it.

It was thus evident that although mutilations do not necessarily prevent, they certainly arrest the natural period of change, both as regards that of the larva, and also its passing into the pupa state.

I have already stated that at the commencement of the eighth day from the operation, May 31st, only five specimens remained out of the twelve of the younger individuals first operated on. At this time they entered their last skin as larvæ. The condition of these specimens after casting their skins was exceedingly interesting. One of them had had the whole of the three legs on the left side of the body either partially or entirely removed. This individual changed its skin during the time I was watching it. No hæmorrhage whatever occurred from either of the injured limbs, the wounds in which had become completely healed. But no new legs had yet been formed, although there were indications that new parts might perhaps make their appearance at the next change, as the basal joint of each leg had become slightly elongated. In a second specimen the intermediate leg on the left side had been removed almost close to the body, and the remains of the basal joint in this also was slightly enlarged. In a third instance the intermediate leg on the left side had been cut off quite close to the body, and yet the larva had undergone its change without any hæmorrhage; the wound was completely healed, but there was scarcely any development of the injured surface. In the fourth example also the first and second legs on the left side had been cut close off, but the basilar joints in these were elongated, and the insect cast its skin without difficulty. In the fifth specimen, which cast its skin during the very moment I was examining it, the facts were still more satisfactory. The middle leg on the left side had been removed, but the basilar joint, as in the other instances, had become elongated. Besides this, a portion of the posterior leg on the same side had been removed at the tibial joint, and this *had now been reproduced with the tarsus and claw.* It now formed a short leg, very obtuse at its extremity, with the minute black claw sunk in its apex. This fact sufficiently proved to me that a power of reproduction exists in insects which undergo a complete metamorphosis, as well as in those which do not change their form, and it led me to watch with greater assiduity the passing of these individuals into the pupa state.

At the expiration of nine days from the commencement of the experiments (June 1st), one of the larvæ, that was nearly full-grown when operated on, suspended itself to enter the pupa state. At that time there were only seventeen specimens still living out of the twenty-eight originally employed, and four of these died soon after. There then remained two of the oldest, six of the next age, and, as above stated, five of the youngest. The eight oldest specimens had all changed to pupæ by the 5th of June; but the remaining five continued to feed until the 6th, between which and the 9th, the seventeenth day after the operation, these also had become pupæ. I was now much gratified to find that most of them gave distinct evidence of reproduction having taken place. In some of them the *tibial* and *tarsal portions* of the legs had been restored; in others *entire limbs had been reproduced* (fig. 5. *f. g.*), while in two or three instances the experiment appeared to have entirely failed. I waited, therefore, with much eagerness for the development of the perfect insects.

The first specimen came forth early on the morning of the 14th of June, the twenty-second of the experiment, having remained in the pupa state only eleven days and seventeen hours, during which the temperature had ranged from 61° Fahr., at which it entered the pupa state, to 76° Fahr., being 71° Fahr. at the time the insect came forth; from that time to the 17th of June, the twenty-fifth of the experiment, eight perfect insects made their appearance. The longest period that any of them remained in the pupa state was eleven days seventeen hours, and the shortest ten days fourteen hours; thus most directly proving the influence of increased temperature in hastening development; the usual length of time which this insect remains in the pupa state, at a medium temperature of 60° Fahr., being fourteen days. In two of these specimens no reproduction of the limbs had taken place, but in the six remaining ones the reproduction was complete. In one specimen (fig. 6.) the entire intermediate limb had been reproduced (*g*), but it was much smaller than the other limbs. In the other specimens the tibial and tarsal joints had been restored, and always the minute claw. In some instances the tarsal joints were very short, but their number and relative proportions were usually maintained, while in others the tibia was developed to its full extent, but *without its articular spines* (fig. 6 to 13.), thus coinciding precisely with what I have already stated in regard to the irregular development of the armature of reproduced limbs in the Myriapoda.

The remaining five specimens were developed between the 18th and 20th of June, the last individual having made its appearance at an early hour of the morning of the present day (June 20), having remained eleven days and four hours in the pupa state, which condition it entered at a temperature of 71° FAHR., and left when it was only 63° FAHR. In two of these instances also there was only an abortive attempt at reproduction; the limb was microscopic in size, and imperfect (fig. 15 to 16.), but in the other three the reproduction was very complete.

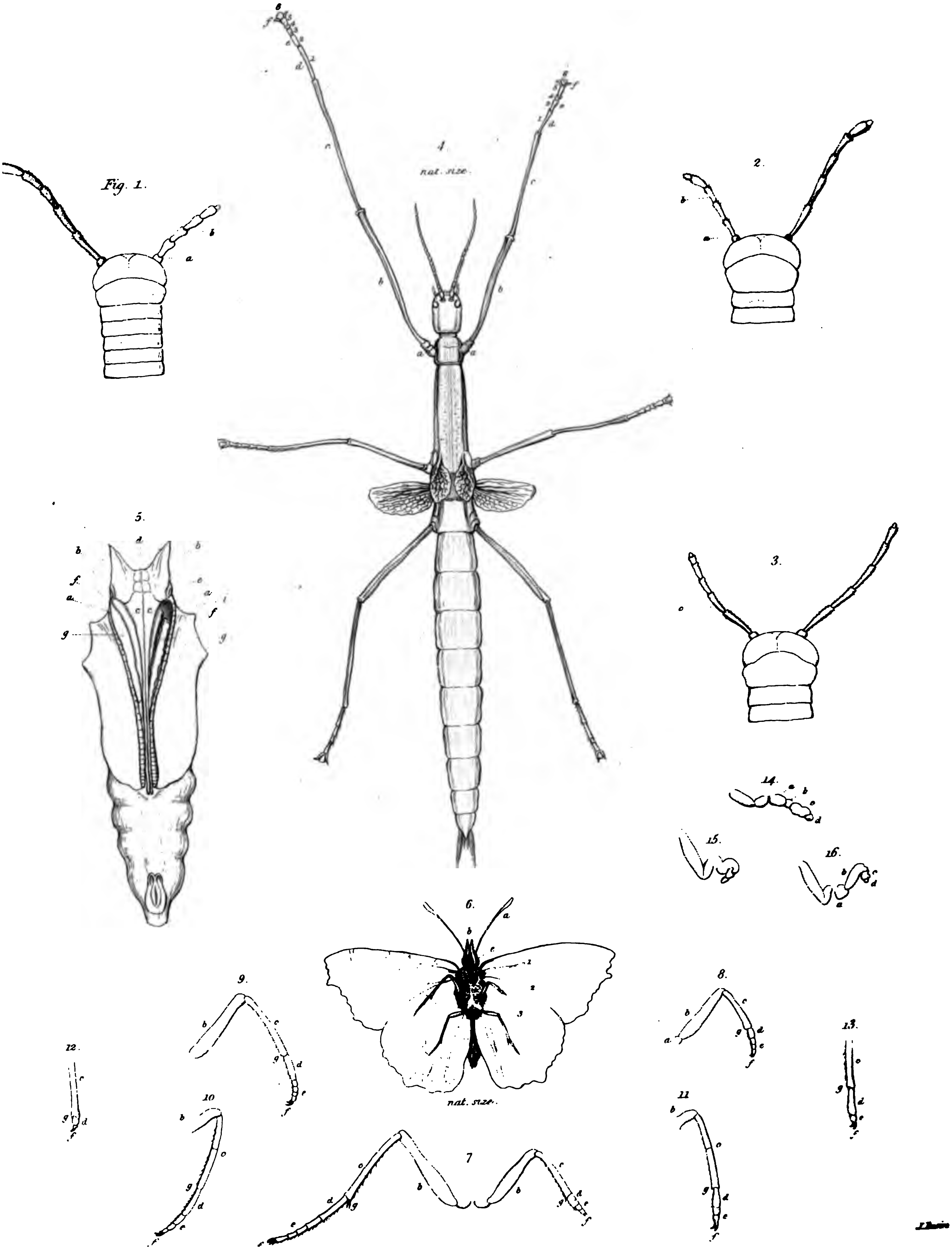
It is a matter of great interest to ascertain to what the non-production of the legs in some of these instances is to be attributed, while a complete reproduction took place in others. Thus, in the last developed specimen the second leg on the left side was reproduced, but the third one was not. This fact appears at first to support the opinion that the reproduction of lost parts depends on the existence of special structures, situated in some portion of the base of the limb, the removal of which prevents the redevelopment of the lost part. But this conclusion is opposed by the fact, that even in those instances, in these experiments, in which the entire limb, with the coxa or basilar joint was removed, a new limb was afterwards produced, or the merest possible rudiment of a limb was developed, while in others there was no indication of it whatever.

When an entire limb is reproduced it is always composed of its *essential* parts (fig. 4.),—coxa, femur, tibia, tarsus and claw. Besides being inferior in size, the tarsus is often deficient in the number of its joints; and the *subsidiary* parts of the limb, the articular spines, are almost always absent. This is more especially the case when a limb has been divided in the femoral or tibial joints, and the reproduction of the limb has, in consequence, been only partial. But in all of these cases the terminal part of the organ, the *claw*, is invariably reproduced. This was strikingly shown in some specimens of partial reproduction, in which the claw was formed at the extremity of a metatarsal joint, or when one or more of the tarsal joints were wanting.

It is thus sufficiently clear that a power of reproduction of lost parts is common to the whole of the Insecta and Myriapoda; and that it may take place in insects that undergo a complete metamorphosis, as well as in those which do not change their form. It yet remains to be shown in what way this regeneration of parts takes place. The fact that it commences in insects and Myriapoda in any portion of an organ that may be wounded, or that it may occur, as in Spirostreptus and other *Iulidæ*, where the entire organ with its basal portion has been removed, seems to lead to the inference that it is not confined to special parts, but exists equally in the whole of the organized tissues.

The general conclusions to which I have been led by these investigations are,— *First*, that slight wounds of the body in larva are always healed, except when there is any protrusion of the viscera, or, as in the higher Vertebrata, when hæmorrhage

Reproduction of lost parts in Myriapoda and Insecta.



J. Basire

takes place to a very great extent. *Secondly,* that very severe wounds also are frequently healed; as, for instance, those attendant on excision of an entire limb. *Thirdly,* that protrusion of the viscera takes place from small wounds when these are in the line of action of the principal muscles of the body. *Fourthly,* that the healing of wounds in these animals depends, in the first instance, on an arrest of the hæmorrhage by coagulation of the effused blood, and the formation of a clot, as in the Vertebrata. *Fifthly,* that coagulation is a property of the blood in these Articulata, exactly as in the Vertebrata. *Sixthly,* that coagulation is not so complete in the former, but begins to take place in nearly the same time as in the latter. *Seventhly,* that a complete union of the wounded parts takes place beneath the eschar formed by the clot on the wounded part. *Eighthly,* that after this union the injury begins to be repaired by the development from the injured surface, of parts corresponding to those which have been removed. *Ninthly,* that at least one change of skin is necessary to the production of a new limb, when the injury has been severe, or the entire limb has been removed. That the removal and reproduction of a part, and the healing of the wound, do not *prevent,* although they certainly *retard,* the natural changes of the animal; and that reproduction of lost parts takes place in the metabolic as well as in the ametabolic Articulata.

Note.—Since this paper was delivered to the Royal Society I have repeated these experiments on the larvæ of *Vanessa Iö* with precisely similar results. The original specimens illustrating this paper are now in the cabinets of the British Museum, together with others showing the same facts in *V. Iö.*—G. N., Sept. 24, 1844.

DESCRIPTION OF PLATE.

Fig. 1. Head of *Iulus terrestris* with the right antenna reproduced.
  a. The original basal joint.
  b. The reproduced joints.—Magnified.
Fig. 2. Head of *Iulus* with the left antenna reproduced.
  a. The original basal joint.
  b. The reproduced joints.—Magnified.
Fig. 3. Head of *Iulus* with a portion of the left antenna reproduced.
  c. The point at which the original antenna was divided, and the reproduction of the new parts commenced.—Magnified.
Fig. 4. *Alopus cocophages,* GRAY, MSS. (natural size), with the right anterior leg reproduced.
  a. Coxa.
  b. Femur.
  c. Tibia.
  d. Metatarsus.
  e. Tarsus
  f. Claw. The third tarsal joint in this foot is not developed.

Fig. 5. Front view of a pupa of *Vanessa urticæ* one hour before the development of the perfect insect (fig. 6.), exhibiting the condition of the first and second reproduced legs in the pupa.

a. The antennæ.
b. The palpi.
c. The elongated maxillæ or proboscis.
d. The front.
e. The eyes.
f. The anterior, or palpiform leg of the insect reproduced, and very much the smallest on the left side.
g. The middle, or meso-thoracic leg, reproduced and diminutive on the left side.
i. A deep excavation on the left side of the pupa which the reproduced limbs are too minute to fill up. This specimen is magnified three diameters.

Fig. 6. The under surface of the perfect insect developed from the pupa, fig. 5. (natural size), the letters as before. The reproduced legs 1 and 2 are not more than one-half the size of the corresponding ones on the opposite side. In 2, four of the tarsal joints exist, but are exceedingly minute.

Fig. 7. The meso-thoracic or middle pair of legs in the same insect magnified three diameters.

Fig. 8. Reproduced meso-thoracic leg of another individual a little more complete.

Fig. 9. Reproduced meso-thoracic leg of a third individual, with the whole of the tarsal joints, and nearly perfect, but without the tibial articular spines (*g*).

Fig. 10. Meso-thoracic leg of a fourth individual still more complete, with the claw (*f*) almost as in the normal state. In this instance the leg of the larva was divided in the tibial joint (*c*), and the reproduction commenced in that part, but even in this instance the articular spines (*g*) are absent.

Fig. 11. Leg divided in the tibial joint, in the *fifth stage* of the larva, and reproduction commenced in that part.

Fig. 12. Leg divided in the fifth stage of larva with the claw formed at the extremity of a mesotarsal joint.

Fig. 13. Leg reproduced in the tibial portion, further advanced.

Fig. 14. Abortive attempt at reproduction of the leg in a specimen in which the limb was removed after the larva had entered its fifth stage.

Fig. 15. Abortive attempt at reproduction of the posterior or meta-thoracic leg in a specimen in which the limb was removed while the larva was in its *fourth stage*, and in which an entire new limb (fig. 9.) was formed in the same insect.

Fig. 16. Rudimentary abortive leg in a specimen operated on its fourth stage as a larva.

All the figures from 7 to 16 are magnified three diameters.

X. *On the Comparative Anatomy of the Thyroid Gland. By* JOHN SIMON, *Esq., Assistant-Surgeon to the King's College Hospital, and Demonstrator of Anatomy in King's College. Communicated by* JOSEPH HENRY GREEN, *Esq., F.R.S., Senior Surgeon to St. Thomas's Hospital, Professor of Anatomy to the Royal Academy, &c. &c. &c.*

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FEW portions of comparative anatomy appear in a less satisfactory condition than that relating to the organs which have been classed together as glands without ducts. Since any attempt to illustrate the obscure physiology of these bodies must of necessity be founded on a precise knowledge of their distribution in the animal kingdom, the deficiency cannot be considered unimportant; and I accordingly venture to hope that the following details may not appear devoid of interest to the Royal Society.

In recent researches I have had occasion to examine how far the presence of a *thymus gland* extends in the scale of organization: in the present paper I confine myself to the comparative anatomy of the *thyroid body*; and I hope, on some future opportunity, to communicate the result of similar investigations in regard of the remaining two organs of the class, viz. the *spleen* and *supra-renal capsule.*

In pursuing the present subject, and particularly in that part of it which treats of Reptiles, I have been under the greatest obligation to my friend Mr. GRAY of the British Museum, by whose kindness I have enjoyed opportunities of examining many animals which I could not otherwise have procured. I have likewise owed much to the liberality of the Council of the Royal College of Surgeons, who have permitted me access to their rich assortment of store-preparations.

The careful dissections of MECKEL and CUVIER (as recorded in the former's Abhandlungen aus der menschlichen u. vergleichenden Anatomie u. Physiologie, Halle, 1806, and in the latter's celebrated lectures) leave no question as to the universal existence of a thyroid gland in the class of mammiferous animals. It is therefore unnecessary to dwell upon this point, and I proceed at once to consider the anatomy of the gland in the other classes of Vertebrata.

I. *Birds.*

Some writers on the comparative anatomy of Birds have described "two glands, one on each side of the trachea, very near the lower larynx, and frequently attached to the jugular veins; which they regard as the analogues of the thyroid gland[*]."

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[*] OWEN in Cyclop. of Anat. vol. i. p. 348; CARUS, Vergleich. Anat. § 741.

They were first, I believe, mentioned by **Perrault**[*], and were afterwards described in several genera of Birds by **Ballanti**[†] and **Uttini**. Various later observers have since noticed these bodies; some considering them as thyroid glands; while others, among whom are **Meckel**, **Cuvier** and **Haugsted**, entertain a different opinion of their nature.

In all such uncertainties the microscope is the only conclusive test. By repeated and careful examinations, I have satisfied myself that the ultimate structure of these doubtful organs is identical with that of the thyroid gland in Mammalia. They consist, namely, of a dense aggregation of closed vesicles, whereof each is constituted by a delicate homogeneous membrane, is invested by a close capillary net-work, and contains in its interior either floating cytoblasts, or mature cells, corresponding to those of the true glands.

My dissections of Birds have included all the orders, and, in most instances, several families from each: I have never failed to find the thyroid gland, or to recognise its peculiar structure: I accordingly presume that it is universally present in this class of animals.

Of its relative position it is unnecessary to say much more than is included in the notices of previous observers, and I will merely mention that its relation to the larynx seems neither essential nor constant. A more uniform and more important relation is included in the fact, that the gland always corresponds to a particular spot of the vascular system; namely, that it lies on the cervical vessels, and receives its supply of blood just opposite to the point at which the vertebral and carotid arteries diverge to their respective destinations.

II. *Reptiles.*

It is unaccountable that in this class of animals, where the thyroid gland is universally manifest, it should have been so generally overlooked. Where noticed, it has been, with rare and partial exceptions, either mistaken for the thymus, or confounded with it in a common description.

A. *Chelonia.*

Bojanus, in his excellent monograph on the freshwater Tortoise[‡], figures with perfect fidelity the body, which I shall directly mention as the thyroid gland; but he does so under the erroneous impression that it is a thymus, and describes it by this name: **Carus**[§] likewise falls into the same error as to its true nature.

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[*] Déscription de six Otardes, Mém. de l'Acad. t. iii. part 2. p. 319.

[†] **Ballanti** states an opinion of their use which has received pretty general sanction:—"quod vocis organo famuletur glandula hujusmodi in animantibus, id videtur satis comprobare ejus sedes, quæ nunquam non est cum eo organo conjuncta;" and **Uttini**, who continued his researches, specifies this function more exactly, as being "ad vocales chordas opportune emolliendas et humectandas." Comment. Bonon. 1783; De Organo Vocis.

[‡] Anat. testudinis Europ. figs. 66, 156, 173.

[§] *Op. cit.* § 740.

The position of the thyroid in this order of Reptiles is very definite and uniform; it lies in the median plane of the body, just above the base of the heart, between the right and left carotid arteries. The thymus, for which it has been mistaken, lies away from the median line, along the outer side of the carotid on each side, between it and the subclavian artery.

B. *Emydosauria.*

In this order the thyroid gland is a single rounded organ, situate in the median plane of the body immediately above the base of the heart. A careful dissection in this region will first bring into view the thymus gland, which reaches on each side from just below the skull to within the thorax, and conceals the thyroid by the expansion of its pericardiac lobes in front of the base of the heart; these being drawn aside the thyroid gland will be distinctly seen lying between the two carotid arteries. CARUS[*] notices the elongated thymus of the Crocodile, and proposes the vague opinion that it may perhaps fulfil the double function of thymus and thyroid.

C. *Amphisbœnia.*

The thyroid gland in the Amphisbænians occupies exactly the same site and relations as in the true Serpents.

D. *Sauria.*

In this order it is not quite so easy as in the preceding ones to verify the existence of the gland, for it occupies different positions in different families, and is therefore very likely to elude superficial search: in some it is single and mesial, in others double; in some it lies high in the neck, in others low.

1. Among the *Lacertidœ*, the arrangement of the gland is not quite constant for the family. In the true Lizards, and in the Teius, the gland is single, and of considerable transverse diameter, being so situated as to overbridge the trachea a little above the chest: in the Monitors, on the contrary, it is double; one portion is placed on each side of the neck, in front of the carotid artery, and is connected with the inferior extremity of the corresponding half of the thymus gland.

2. Among the *Iguanidœ* likewise the anatomical relations of the gland are not quite uniform: in the *Agamœ* and *Iguanœ* it is single, and lies transversely across the trachea; while in the *Istiurus*, as in the Monitors, it consists of two portions, one lying in front of each carotid low in the neck.

3, 4, 5. Among the *Geckotidœ*, *Chamœleonidœ* and *Scincidœ*, the same general form prevails as in the true Lizards; the gland is single, and elongated transversely so as to reach across the trachea. In the Chamæleon it is rather higher (nearer to the os hyoides) than in the other families, and is overhung by the sacciform dilatation of the larynx. TREVIRANUS[†], in his dissection of the *Chamœleo carinatus*, noticed this body, and suggests of it that it "may be compared to a thyroid gland."

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[*] *Op. cit.* § 740.

[†] Beobachtungen aus der Zootomie, p. 87.

E. *Ophidia.*

In the true Serpents the thymus and thyroid are in such close juxtaposition, and are in many genera so additionally obscured by the presence of a large fat body, that it is not easy to judge, from the vague descriptions of authors, how far the thyroid gland itself has actually been discerned. The organ which **Blasius**[*] described as a thymus "vasis circa collum situatis accumbens, firmæ admodum conditionis, hordei magnitudinem vix excedens," was probably the thyroid gland; **Charas**[†] likewise figured it faithfully, though with the same mistake as to its nature. **Cuvier** had certainly dissected it, and describes its exterior conformation with his wonted accuracy, stating his impression that it is "analogous to the thyroid gland."

The following description applies to all the true Serpents:—The gland lies, as in the Crocodile, just above the base of the heart, between the right and left carotid arteries: it is a little hidden by the thymus of each side, which lies on the carotid for some distance from the pericardium upwards; and in those genera which possess a fat body (as is, for example, eminently the case with the Python) this large organ lies conspicuously in front of both the thymus and thyroid.

F. *Batrachia.*

Among Batrachia, **Carus**[‡] has recognized the thyroid glands of the common Frog; but his statement of their nature appears, like most of the opinions I have quoted, to be delivered vaguely and with hesitation. The organs which he represents are unquestionably thyroid glands; they are situated on the carotid arteries, just beside the cornua of the hyoid bone, one on each side. **Huschke**, in adopting **Carus**'s description, suggests that these bodies probably have their origin in the shrinking of the branchiæ, and he proceeds to apply the theory so obtained to the thyroid gland in other animals, stating the common mode of origin of this organ to lie in the transformation of the branchial arches in the early embryo[§]. But this hypothesis appears sufficiently refuted by the anatomy of the *Menobranchus lateralis*; for in this perennibranchiate reptile the thyroid gland exists no less certainly than in those which possess the branchial apparatus only for a time. I have found the gland in this animal, consisting of two symmetrical portions connected with the inferior border of the os hyoides, one on each side, at the junction of the body and lateral portions of that bone. In the Menopoma I have likewise detected the gland, occupying nearly the same relative position as in the Menobranchus. In the Siren and Proteus I have had no opportunity of making satisfactory examinations.

In the Salamandridæ the same arrangement prevails as in the Ranidæ.

In the anomalous *Lepidosiren paradoxa* the thyroid gland appears also to exist.

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[*] Anat. Animalium, Amst. 1681.

[†] Nouvelles Expériences sur la Vipère, ch. v. sect. 3. fig. 2. D.

[‡] *Loc. cit.*

[§] Oken's Isis, 1826, p. 621.

Bischoff, in his elaborate dissection of that animal[*], discovered a minute glandular organ, adjoining the anterior extremity of each isolated cornu of the os hyoides, and inclined to consider it as a salivary gland. I have had no opportunity of examining this rare reptile, but Bischoff's account is so complete and circumstantial as almost to supply the absence of personal observation. The minute body in question cannot be viewed as a salivary gland, for it is expressly stated by Bischoff to be destitute of an excretory duct. This last point almost decides its true place in the animal economy; and further, its position, in regard to the hyoid bone, is so exactly that occupied by the thyroid gland in the Menopoma and Menobranchus, that (from Bischoff's description) I cannot hesitate in ascribing to it the same nature.

III. *Fishes.*

I am not aware that any author has hitherto suggested the possible existence of a thyroid gland amongst this class of vertebrate animals.

In many fishes it is undoubtedly present; I have found it in the Carp (*Cyprinus*), Anableps[†], Pike (*Esox*), Exocetus[†], Cod (*Gadus*), Haddock (*Morrhua*), Whiting (*Merlangus*), Eel (*Anguilla*), Sturgeon (*Acipenser*), Callorhynchus[†], Shark (*Squalus*), Skate (*Raia*), and questionably in the Lamprey (*Petromyzon*).

It has appeared, on the other hand, to be absent in the Perch (*Perca*), Mullet (*Mugil*), Gurnard (*Trigla*), Mackerel (*Scomber*), Tench (*Tinca*), Salmon (*Salmo*), Trout (*Salmo fario*), Herring (*Clupea*), Plaice (*Pleuronectes*), Holibut (*Hippoglossus*), Turbot (*Rhombus*), Sole (*Solea*), Cyclopterus, Gymnotus and Balistes[†].

This part of my inquiry has been attended with extreme difficulty. According to varying circumstances the gland may occupy any one of three different positions;—these positions, moreover, related to each other (as would appear at first sight) by no very obvious analogy. It was long after discovering a thyroid gland in the Skate, and vainly searching for it in the corresponding region of the body in other fishes, that a second probable spot occurred to me, in which I succeeded in finding the gland in the Cod, Haddock and Whiting; and it was yet longer before I ascertained the organ's third occasional site. Such having been the case, it has of course been no easy matter to arrive at trustworthy results as to the absence or presence of the gland in each particular instance. In forming the negative conclusion, there was always some fear of having overlooked the organ,—always some doubt of its occupying an unexplored space. The positive certainty, which alone is valuable in investigations of this nature, cannot often be derived from examining preparations preserved in spirit; and, therefore, although I have made many such dissections, I refer to them in very few instances, and draw my inferences from those only which I can quote with entire confidence.

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[*] Lepidos. Parad. anatomisch untersucht und beschrieben, Leipzig, 1840.

[†] In those marked by a dagger, I have been obliged to trust to preparations preserved in spirit; and these dissections—especially with a negative result—are never quite so satisfactory as if performed on the recent body of the animal.

The positions in which I have found the gland are the following, viz.—

1. In those cartilaginous fishes* which possess it, as likewise in the Eel, it is a single organ, and is situated in the median line, in connexion with the anterior surface of the cartilages, which bind together the branchial arches of the opposite sides of the body. Within this line it may be more or less removed from the mouth of the animal, sometimes advancing so far upward as to come into contact with the lingual bone; but its position is always defined, as the spot where the great trunk of the branchial aorta distributes its terminal branches. It lies in the angle of this bifurcation, and sometimes (as in the Sturgeon) extends some little way behind it; it is covered by the sterno-hyoid or sterno-maxillary muscle, and also by the mylo-hyoid and genio-hyoid, when these are present. Situated at the anterior extremity of the first branchial arch, it receives its supply of blood by means of a recurrent branch given off in this direction by the first branchial vein, while yet within the gill. It never receives the smallest share of supply from the branchial artery with which it is in contact.

2. In the *Gadidæ* the gland is double; one portion lies on each side, not as in the last case, at the anterior extremity of the first branchial arch, but near its posterior or vertebral end. Here it occupies part of a recess which is bounded by the gill below, and above by the outer extremity of that transverse fold of mucous membrane which limits the extent of the palate; it is merely covered by mucous membrane, which leaves it apparent to the eye without need of any express dissection. Its vascular supply is reflected to it from the ophthalmic artery, which arises, before the formation of the systemic aorta, from the first branchial vein close to the origin of the proper encephalic artery.

3. In the Carp, Anableps, Pike and Exocetus, the gland is placed at the inner extremity of the same duplicature of mucous membrane, and more toward the palate, so as to lie upon the fibres of the pterygoid muscle. It requires more dissection, in order to be made apparent; in the Carp especially it is at considerable depth, being hidden by the extraordinary thickness of the soft palate, and imbedded between the surface of the pterygoid muscle and the outer extremity of the branchial bone.

Amid these differences in the relative anatomy of the gland there is constancy in respect of one point, which I am inclined to consider essential; the organ, whether placed in the median plane or otherwise, whether at the vertebral, or at the hyoidal extremity of the gill, is always so placed as to receive its blood from the first branchial vein, and is thus brought into connexion with the encephalic nervous centre by a certain community of vascular supply.

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* The questionable trace of a thyroid, noticed in the *Petromyzon marinus*, was in a depression of the base of the skull, between the palate and the posterior confluence of the branchial veins; it would resemble the above in being single, but otherwise would be nearer to the thyroids of the osseous fishes.

Nothing could at first sight appear more capricious and uncertain than the presence of the gland in fishes; it would seem almost hopeless to account for its being found in the Carp, yet not in the Tench; in the Eel, yet not in the Gymnotus, &c. Further research, however, tends to justify the belief that its distribution is governed by a simple and uniform law; namely, by the existence or non-existence of another organ, with which its presence alternates. Since this law, if discoverable, must be an important step toward ascertaining the function of the thyroid gland, I beg leave to offer a few observations on the organ alluded to.

In many fishes (take for instance any one of our common Acanthopterygii or Pleuronectæ) there exists a peculiar appendage to the branchial apparatus, first described by Broussonet[*], and subsequently with more detail by Meckel[†]. It has the aspect of a minute supplementary gill, and is situated between the outer extremity of the palatine duplicature of mucous membrane on the one hand, and the dorsal attachment of the first true gill on the other[‡]. It must not be confounded with the large opercular gill, found in some fishes (as for instance very largely in the Sturgeon), from which it essentially differs.

The vascular supply of this small appendage is a point of extreme interest in its history. Its vessels communicate on the one hand with the systemic veins about the base of the cranium, on the other, by a single long trunk with the first branchial vein. Rathke[§] and Cuvier[||] consider the former to be its afferent, the latter its efferent vessel. But it surely must be erroneous to describe any part of the circulation in a fish as *commencing in a systemic vein, and attaining a branchial vein without having previously traversed the heart*: and I cannot doubt that the supply of this branchiola is after the analogy of organs in the systemic circulation,—that it commences, namely, in the branchial vein, and terminates in those veins which are conveying blood to the heart[¶].

The supplementary gill occupies in those fishes which possess it, exactly the same relative position as the thyroid gland in the sub-brachian Malacopterygii: a careless examination of the Cod, Haddock, or Whiting, where the gland shines through the membrane, might almost lead an observer to suppose that the supplemental branchia was there, as in the Pleuronectæ; so similar is the arrangement in the two cases. Equally exact, according to the above argument, would be the agreement of the two organs in respect of their vascular supply; both deriving their afflux of blood from the first branchial vein, both rendering it up again by the readiest channel toward the heart, both as it were participating in the cerebral circulation.

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[*] Mém. de l'Acad., 1785, p. 174.

[†] Vergleich. Anat. vol. vi. p. 179.

[‡] It is often a little obscured by the free edge of the palate overhanging it.

[§] Über den Kiemen-apparat und das Zungenbein, 1832, p. 53.

[||] Anat. Comp.

[¶] The supplemental gill, like the thyroid gland, never derives a branch from the branchial artery; injection driven by the bulbus arteriosus never directly reaches it; but it admits of ready and complete injection by the systemic aorta.

But (it may be contended) this arrangement, which is comprehensible for the gland, is not equally so for the gill; why should this organ, which, in regard of structure at least, is clearly branchial, derive its supply of blood from a stream no longer requiring aëration? It cannot assist the respiratory process, which is already accomplished for the blood arriving there: it cannot do more than maintain the previous oxygenisation of the fluid which traverses it. I can conceive no other theory for the supplemental gill, in agreement with the preceding facts, than one which interprets it as a diverticular appendage to the first branchial vein, and contemplates its uses in reference to the parts supplied by that vessel.

Such then is the organ which,—obtaining the same nutritive supply as the thyroid gland, and occupying a correspondent position,—found only where that gland is absent, absent only where *it* is found,—may fitly be considered as its partial and rudimentary representative*.

The general results of the preceding inquiry are as follows; viz.

1. The thyroid gland, or an organ representing its place and office, may be found in *all vertebrate animals*.

2. It does not appear (as is the case with some organs) to belong to these animals, merely in behoof of the greater *general* completeness of their organization; but seems to have particular reference to that *specific character*, which binds them together as a natural section of the animal kingdom,—namely, the aggregation and more perfect development of their nervous centres; for

3. The gland, shifting its position most variously, yet always maintains an intimate *relation to the vascular supply of the brain*; always is so nourished that it can alternate a greater or less nutrition, according to the activity or repose of that nervous centre.

4. The organ, which in certain fishes represents a rudimental form of the thyroid, is plainly a mere *diverticulum* to the cerebral circulation: in the remaining fishes (where a more perfect thyroid exists), as likewise in the ascending scale of vertebrate animals, there is no essential change from the vascular organization of the branchiola; there is simply the super-addition of a glandular structure. The thyroid is but a higher development of the branchiola: what was a mere capillary plexus, now has gland-cells intermingled with its texture. Probably then the use of the secretory actions occurring in the thyroid gland is to be found in harmony with the obvious

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* The Sturgeon, in addition to its thyroid, has a very small supplementary gill; so small, however, and so rudimentary, that this fish cannot be considered an exception to the general rule, but rather as an additional confirmation of its accuracy.

intention of its vascular supply; as the latter is diverticular, so we may expect the former to be vicarious, or alternative.

Such are the conclusions which Comparative Anatomy may warrant, and beyond these the proposed scope of the present paper does not permit me to advance. I would but in ending remark, that the views here suggested seem to me to receive equal sanction when contemplated in the light of the other physiological sciences. The peculiarly occasional and intermitting character of the cerebral functions,—the morphology of the thyroid gland, and its evident adaptation (as I have elsewhere shown) for a merely temporary, and, as it were, alternative secretion,—the known ability of arteries to regulate and proportion the supply of blood transmitted through them,—the diseases of the gland,—its turgid throbbing in hysterical lipothymia,—the mysterious relation of goître and cretinism;—these are topics on which it would be inconvenient now to dwell, but a glance at which is sufficient to show that comparative anatomy by no means exhausts the available arguments for the connexion suggested.

XI. *Researches into the Structure and Development of a newly discovered Parasitic Animalcule of the Human Skin—the* Entozoon folliculorum. *By* Erasmus Wilson, *Esq., Lecturer on Anatomy and Physiology in the Middlesex Hospital. Communicated by* Robert Bentley Todd, *M.D., F.R.S.*

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In the June Number of Muller's Archiv (for 1842) there appeared a paper from the pen of Dr. Simon of Berlin, announcing the discovery of certain animalcules, which he regarded as Acari, in the sebaceous substance of the follicles of the human skin. After perusing his account of these singular creatures I was induced to engage in the inquiry, and was so much interested in what I saw, that I devoted six months of exclusive labour to the study of their structure and mode of development. The result of my research is at variance with the description of their structure given by Dr. Simon; it corroborates Dr. Simon only in the general fact of the existence of these animals and their diversity of form, while it offers several new and original observations for consideration. Among the latter I may refer especially to the anatomy of the head, which Dr. Simon regards as composed of certain moveable organs, but which in reality is distinct from those organs; the discovery of eyes; of a power of retracting the head within the thorax; of ova; of a remarkable embryonic form; and of the progressive development of the young animal.

The situation of the animalcule in the zoological system is a question still to be determined, and it is one on which I have felt unwilling to speculate until a complete description of the creature shall have been placed before scientific entomologists. The name given to the animal by Dr. Erichson of Berlin and adopted by Dr. Simon, namely *Acarus folliculorum*, is founded on the erroneous view of the anatomy of the head and mouth, put forth by the latter gentleman. The animal is not an *Acarus*, for it has no haustellum; nor is it an *Arachnidan*, for it possesses a distinct head, susceptible of retraction within the thorax, and an abdomen most indubitably annelidous in structure. Under these circumstances I have followed, in the present paper, the suggestion of Dr. Todd, and have made use of the term Entozoon, signifying merely an inhabitant of the interior of the body, as a temporary appellation, until a better and more suitable one shall have been invented.

The *Entozoon folliculorum* is found in the sebaceous substance of the hair-follicles; it feeds upon the secretion contained within the sebaceous cells, and its young are produced from ova in the midst of the sebaceous matter. The presence of these animalcules has no reference to disease of the skin or of the follicles; they are met with in almost every person, but are most numerous in those in whom the skin is naturally torpid, in invalids, and in the sick. Their numbers are various; in some persons not more than two or three can be found in a follicle, while in others I have seen upwards of fifteen, indeed the follicle has been completely distended by them. Their position within the follicle is peculiar, the head is always directed inwards, while the tail is directed in the opposite sense; and when a number are present, they have the appearance of being collected into a conical bundle, the large end of the cone being formed by the heads. The situation in which these little animals are most commonly found is the integument of the face, and more particularly that of the nose, but I have also met with them in the follicles of the back, and of the breast and abdomen; I have not yet found them on the limbs.

As regards the size and form of the animalcules there is considerable variety, some of the differences being referrible to growth and development, and others amounting to a specific distinction. They pass their whole existence in the sebaceous substance, undergoing ecdysis repeatedly during their development and growth; and are finally expelled from the follicles with the secretion of those organs. For examination, they are obtained by compressing a follicle and placing the small mass which escapes from its aperture in a drop of olive oil between two plates of thin glass. By a slight movement of the glasses the sebaceous matter may be broken up and distributed without injury to the animalcules, but if much pressure be employed, they will be in danger of being crushed. When prepared in this manner, they may be seen to move with activity for many hours, and they are so tenacious of vitality that I have found them alive in a subject in the dissecting room that had been dead for fourteen days. They are seen very distinctly with an object-glass magnifying fifty diameters.

The perfect animal may be known by the following typical characters: it is elongated in figure, being several times longer than the breadth of its body; and is divisible into a head, thorax and abdomen; the head being more distinct from the thorax than the latter from the abdomen.

The head is subconical in form, obtusely truncated anteriorly and depressed. It is connected with the thorax by means of a narrow segment formed by a fold of integument, and can be withdrawn within the thorax so as to be completely buried from sight. When the head is protruded the outline of the narrow segment is distinguished by two slight grooves, which are seen with the microscope as boundary lines; but when the head is retracted the segment is seen as a thick folded border, which constitutes the anterior extremity of the animal.

The truncated extremity of the head is composed of two moveable, arm-like organs, which lie side by side, and together with two intermediate antennæ-like organs, constitute the entire breadth of the snout. The cephalic arm-like organs or palpi are cylindrical at their bases, where they are continuous with the general tegument of the head, and become somewhat smaller and prismoid towards their distal end. In the latter situation they are truncated and present a flattened extremity. They appear to be formed by a bifurcation of the head and by the prolongation forwards of the divided portions, to an extent which is about equal to one third of the length of the head. In structure, the cephalic palpi are composed of three or four annulate segments connected by capsular membranes, the last segment or carpus having its flat and triangular palm furnished with four or five membranous claw-like phalanges with obtusely pointed extremities. On the outer angle of the penultimate segment is a prominent tubercle; which has the direction of the axis of the arm. The cephalic palpi are furnished in their interior with muscular fibres, which form a thin stratum beneath the integument, and are continuous posteriorly with the general muscular system of the animal. Of this muscular apparatus, the flexor and extensor fibres are most strongly marked.

The motions of the cephalic palpi are extensive and powerful in the direction of flexion and extension, but very limited in the sense of abduction. By virtue of the laxity of the capsular membranes of their annulate segments, they also admit of retraction. The actions of flexion and extension aid the animal in progression, and in consequence of the inward obliquity of their movement, they also serve the office of organs of prehension, by conveying directly to their mouth portions of sebaceous substance, from which the animal may suck the juices.

The upper surface of the head is depressed, sloping gradually downwards and forwards from the occiput to the extremity of the snout, which is either curved suddenly downwards or slightly upwards, according as the animal is seen in the state of flexion or extension of its cephalic palpi. Along the middle of the head in its longitudinal axis is a slight groove caused by the prominence on each side of the cephalic palpi; and lodged in this groove is a flask-shaped flattened organ (labrum ?) which forms a part of the base of the head behind, and terminates anteriorly opposite the bifurcation of the cephalic palpi in a linguiform point. The flask-shaped organ is slightly curved in its form; its upper surface being smooth and convex, the under concave. From the concave under surface there appear to proceed four pairs of jointed tentacula, which in the first instance pass forwards, and becoming perceptible beyond the end of the flask-shaped organ, give rise to the appearance of a succession of progressively diminishing rounded segments, and then bend downwards to either side of the mouth of the animal. Proceeding also from this organ as far back as the base of the neck of the flask are two larger, antennæ-like tentacula, which seem to arise from its under part at each side and run forwards parallel with the neck of the flask and its segmented prolongation. Immediately in front of the latter, the larger pair of tentacula approximate and pass onwards parallel with each other to near the extremity of the snout, where they curve downwards and backwards to the front of the mouth. These tentacula are slightly constricted from point to point, the constrictions probably performing the office of joints, and at their termination are slightly curved outwards. They are capable of a moderate degree of movement in the direction of flexion and extension.

The flask-shaped flattened organ terminates posteriorly in a narrow elongated process which is received between two oval, flattened organs within the head, and these latter are connected with two large reniform organs which constitute the bulk of the head. Moreover, it is to these oval-shaped organs that the muscular apparatus intended to retract the head is attached. The oval-shaped organs are marked in the middle by a small indistinct circle, and on each side by a dark spot, produced apparently by a deposit of pigmentary matter.

On the under surface of the head in the middle line, and occupying the anterior half of its length, is an oblong opening, the mouth; it is surrounded in front and on the sides by a broad and raised border, consisting of a number of tentacula, four pairs of which may be distinguished as being superior and three inferior. There are consequently no less than sixteen tentacula surrounding the aperture of the mouth; the central pair, or antennæ-like tentacula, proceed, as I have before remarked, by the side of the neck of the flask-shaped organ, while the four remaining pairs appear to originate from the under surface of that organ. The three pairs of inferior tentacula are productions of the integument from the posterior boundary of the mouth, the external pair being the longest, and the innermost pair merely rudimentary. Behind the mouth the boundaries of the pharynx are seen through the transparent integument.

The tentacula are capable both of lateral and central approximation, and by these movements effect a closure of the aperture of the mouth. They cooperate in the act of prehension and detention of food, and by their close contact constitute a temporary haustellum by which the fluids of the nutritive mass are expressed and imbibed by the animal.

Immediately within the tentacula are situated a considerable number, probably from four to ten pairs, of maxillæ which form an internal border to the mouth. The maxillæ are elongated cylindriform organs, projecting by their free extremity one beyond the other along the border of the mouth, from its posterior to its anterior boundary, and corresponding by their axes with that of the head. They are apparently attached to the pair of large reniform bodies which form the principal bulk of the head, and by their shafts constitute the walls of the pharynx.

The maxillæ, like the tentacula, are capable of close approximation, both in the lateral and central direction, and are consequently well adapted to assist the latter in the office of suction, and at the same time to masticate substances presented to them by the tentacula. In the latter action the tentacula would hold the nutritive substance, while the maxillæ are engaged in its trituration and deglutition.

Within the head, and constituting the bulk of this part of the animal, are two oval-shaped or reniform bodies of an opake white colour. These bodies are slightly flattened from above downwards in conformity with the shape of the head; they are broad in front, somewhat narrower behind, where they are separated by a narrow interspace, convex on their outer border, and flattened on the middle line. In the latter situation they are excavated in front to form the pharynx, and behind the mouth appear to be continuous for a short extent by means of an isthmus of communication. When these bodies are examined on the upper surface, a dark globular body will be seen to be imbedded in the substance of each near its anterior extremity. This globular body is an eye of the simple kind, and is surrounded by a circular line representing an orbit. On the middle line the mode of junction of the reniform bodies is concealed by the flask-shaped organ, and posteriorly it is to these bodies that the oval-shaped pieces of the flask-shaped organ are attached.

These reniform bodies constitute, as I have before remarked, the essential part of the bulk of the head; they give support to the eyeballs; they form the pharynx; they afford a point of connection to the maxillæ, and by means of the flask-shaped cephalic organ, they give attachment also to the superior tentacula. When retracted into the cavity of the thorax, these bodies may be very distinctly seen through its thin and transparent integument. Besides the movement of retraction within the thorax, the head admits of flexion and extension, and of a lateral flexion produced by rotation on its own axis. The thorax is the largest and broadest part of the animal; it is flattened upon its ventral surface, convex on its dorsal and lateral surfaces, narrower in front than behind, and somewhat larger toward the middle than at either extremity. It is composed of four broad and continuous annular segments, which are distinguished on the ventral surface of the thorax or breast by four strongly-marked transverse lines, and on the dorsal surface by as many broad and shallow transverse grooves. These shallow grooves are produced by a convexity of each of the segments from before backwards; they correspond inferiorly with the spaces between the legs, while the convex portion of each segment is on a line with the attachment of the legs. With the ventral surface of each of these segments on each side of the breast, the four pairs of legs of the animal are articulated.

The ventral surface of the thorax is flattened, and the epidermic covering is thicker in this situation than on the rest of the body. Running along the middle line of the breast, the whole extent of the thorax, is a double line (sternum) formed by two ridges which are broken at short distances and are continuous with the four transverse thoracic lines. The latter also consist of double ridges and run outwards, forming the boundary mark between the thoracic segments. The most anterior of the transverse ridges commence at the extremity of the median ridge, and pass obliquely forwards and outwards at each side to the space between the base of the anterior leg and the collar of the neck, forming the anterior boundary of the thorax on its ventral aspect. These ridges are slightly curved in their course, the convexity being directed forwards, and taken together, give the idea of a bifurcation of the median ridge anteriorly. The second pair of ridges pass nearly horizontally outwards to the groove between the first and second pair of legs making a very gentle curve, the convexity of which is directed backwards. The third pair of ridges are more horizontal in their direction than the preceding, and run to the groove between the second and third pair of legs, also forming a gentle curve, whose convexity is backwards. The fourth pair of ridges proceed obliquely outwards and backwards on each side, and terminate at the groove between the third and fourth pair of legs. There is no line of separation between the thorax and abdomen, and the median ridges gradually diminish in their prominence on the last thoracic segment, until at the boundary of the latter they are lost. The spaces of the breast included between the transverse ridges in front and behind, and the median ridge and base of the legs laterally, are irregularly quadrangular in form, and increase in breadth from before backwards in consequence of the greater separation between the legs.

The lateral and dorsal portion of the thoracic segments is marked on its surface by a number of transverse lines situated at minute but regular distances. The spaces between these lines represent so many narrow plates which are unbroken from the base of the lateral portion of each thoracic segment across to a similar point on the opposite side, and overlap each other slightly from before backwards. On the convexities of the thoracic segments on each side, near their bases, the plates converge and become more imbricated than in their upper portion. By this arrangement a small triangular interval is left in the concavities of the segments which is occupied by short supplementary plates.

The thorax admits of flexion to a limited extent, both in the antero-posterior and in the lateral direction, and of a slight degree of retraction in the longitudinal axis.

The legs are four in number on each side; in general form they are conical, broad at their bases, where they are attached to the side of the under part of the thorax, and truncated at their free extremities. They are composed of three segments; the proximal segment covers by its articulation a considerable expanse of surface, extending for some distance inwards upon the breast, and outwards upon the side of the thorax. In longitudinal extent it occupies very nearly the entire breadth of the thoracic plate. This segment resembles in its form the base of a cone obliquely truncated from before backwards; its anterior depth being considerable and the posterior very narrow. On the outer side of this segment, and along its base and inferior border, are situated several spinous tubercles, and at the extremity of the anterior margin is one of larger size than the rest; it is curved backwards. The proximal segment is articulated with the thorax by means of a loose capsular membrane, which permits of a trifling degree of retraction of the segment within the cavity of the thorax, and also allows of a slight degree of motion in all directions; the principal movement of the segment being forwards and backwards. The middle segment is a cylindrical piece articulated with the preceding by means of an exceedingly loose capsular membrane. Its movements are flexion and extension in the antero-posterior direction, and retraction to a considerable degree. The antero-posterior movements are very extensive; the former almost buries the middle in the superior segment, approximates the third piece and recurved tubercle of the anterior border of the proximal segment, and performs a sharp, angular flexion posteriorly;

while the latter directs the middle piece nearly horizontally backwards, and converts the posterior projecting angle into a receding angle. The capsular membrane of this articulation during the movements of the segment, is raised into a fold on the side corresponding with extension, and reminds one very forcibly of the analogous manner of articulation of the crural segments in the Lobster. The third segment is short, and admits at a very trifling extent of movement on the extremity of the middle piece. It is flat on its distal surface, and provided with seven or eight digital processes or phalanges, which during the movements of the limb, are one while drawn together and straightened so as to have the appearance of a single conical point, and another while separated and curved, so as to resemble a number of hook-shaped claws. The latter is their more frequent condition.

The contents of the thorax are very indistinct, on account of the general transparency of the animal, and I have been quite unable to detect anything like a proper organ. On two occasions I saw some granules rising and falling in a central direction, being bounded on each side by a faint longitudinal line; this I conceived to be some alimentary substance moving in the œsophagus. The difficulty of perceiving any organ within the thorax is moreover increased by the presence of numerous adipose vesicles which constitute the subtegumentary tissue. On bringing the interior of the thorax to a focus, some faint waving lines may be seen along the sides of that cavity; these are the muscles of the legs, and they are continuous with the retractor muscles of the head; the latter appear to be attached to two ridges which project from the upper and lateral part of the two first thoracic segments. In the upper and anterior part of the thorax I have observed pretty constantly a transparent spot that seems to be an unoccupied space, bounded by the substance of the animal below and by the vaulted transparent integument above. This space has reference to the retraction of the head within the thorax.

The abdomen is the largest of the three divisions of the body, usually several times longer than the thorax, but somewhat smaller in diameter at its commencement than the latter, and tapering more or less to its termination. Its form is that of a cylinder slightly compressed from above downwards, being flatter on its under than its upper surface. The integument of the abdomen is composed of narrow annular segments which overlap each other from before backwards, and become narrower towards its extremity. These segments have a beautiful appearance when seen with the microscope, and give the idea of an exceedingly delicate coat of plait armour. When examined along the edge of the abdomen they exhibit a serrated outline, the serrations being sharp and accurately defined. Upon the under surface of the abdomen, close to its extremity, is a small opening which sometimes appears circular and sometimes elliptical in shape, the long diameter of the ellipsis being directed transversely; this is the anus.

The segmented structure of the abdomen permits of flexion of this part of the animal in every direction, namely, forwards, backwards, and laterally. Indeed, when the abdomen is long, it is frequently seen to present a succession of curves and to assume an undulated position. Besides flexion, the abdomen is capable of contraction both in the longitudinal and horizontal direction. I have sometimes seen one or two horizontal contractions which have straitened the diameter of the cylinder very considerably, and have given it the appearance of being tightly constricted by a string.

The structure of the interior of the abdomen, like that of the thorax, is difficult to determine, on account of the extreme transparency of the animal and great number of adipose vesicles which, in clusters of various sizes, form the subcutaneous stratum. Externally to this stratum is a thin membrane which lines the epidermic case, and which, under compression, I have sometimes seen separated to a greater or less extent from the latter. The more general appearances of the abdominal contents are,—a large, rounded or oblong mass of a light brown colour, situated close to the thoracic extremity; another light brown mass at about one third from the extremity of the tail; an irregular cellular mass between the two former, and a transparent portion at the caudal end. The most anterior of these masses is composed of nucleated granules; in one instance it presented a distinct pouch-like figure with well-defined boundaries, but more usually it is irregular in form, sometimes extending for a short distance into the thorax, and at other times being prolonged by a pointed process backwards. Whatever its form, it is traversed through the middle by a curved, cylindrical canal, which appears to represent the stomach, the dark granules being very probably hepatic corpuscles. The cellular mass which succeeds the gastric organ consists of an assemblage of transparent vesicles of various magnitude, some large and some small. In the midst of these the alimentary canal may generally be traced as a slightly shaded band, somewhat curved in its course. The third mass, namely, that which occupies the commencement of the posterior third of the abdomen, is composed, like the first, of nucleated granules or cells: this mass is smaller than the first; I have been unable to trace the alimentary canal through it, and I am inclined to regard the granules as constituting the ovarium. The remaining part of the abdomen I have described as being transparent and empty of granules; this, however, is not constantly the case, for the granules sometimes extend to the very extremity of the abdomen. In a few instances I thought that I could perceive the latter part of the alimentary canal passing through this part of the animal and terminating by a dilated cloaca at the anal aperture.

In the course of my observations on the *Entozoon folliculorum*, I have distinguished two principal varieties of the adult animal which are marked by strongly characteristic, if not by specific features. The first of these is of large size, fine proportions, and is remarkable for the great length of its abdomen and the roundness of its caudal extremity. The second is characterized by a certain degree of clumsiness of form, shortness of abdomen, and pointedness of the caudal extremity.

The *long* form varies in size from the $\frac{1}{100}$ to the $\frac{1}{45}$ of an inch in length; the latter measurement, that is, somewhat more than a quarter of a line, being that of the longest specimen I have seen. The body of this animal, from the snout to the base of its posterior legs, measured $\frac{1}{250}$, and the greatest breadth of the thorax $\frac{1}{500}$ of an inch. Of the smallest there were two specimens, of which the same measurements were—

Entire length.	Length of body.	Greatest breadth.
$\frac{1}{100}$	$\frac{1}{280}$	$\frac{1}{480}$
$\frac{1}{100}$	$\frac{1}{312}$	$\frac{1}{555}$

Of fifty specimens, the largest number measured in extreme length from $\frac{1}{70}$ to $\frac{1}{60}$ of an inch. In length of body the greatest number measured (in round numbers) $\frac{1}{275}$, in length of head $\frac{1}{1000}$, and in greatest breadth $\frac{1}{500}$ of an inch.

The *short* form varies in extreme length from $\frac{1}{160}$ to $\frac{1}{109}$ of an inch. The shortest specimen that I have met with measured in length, namely, from the snout to the base of the posterior legs, $\frac{1}{330}$, and in greatest breadth, $\frac{1}{550}$. The longest, namely, that which measured in extreme length $\frac{1}{109}$, measured in length of body $\frac{1}{345}$, and in greatest breadth $\frac{1}{530}$ of an inch.

Turning my attention to the development and mode of growth of the Entozoon, I met with some curious results,—results that led me to the conclusion that the two varieties are developed in a manner peculiar to each; that both proceed from ova, but that the larger kind pass through an intermediate developmental form in which the shorter do not participate. Probably this peculiarity may depend on some unknown modification of the elements of nutrition, and, very possibly, on the same cause with that which determines the greater length of the animalcule. In reflecting on this peculiarity I was reminded of the modification which the young of the common earth-worm presents in a soil of variable tenacity, in the one case being extruded from the oviduct of the parent surrounded by a nidamental covering, and in the other in its perfect state. Here is an important modification having reference to the security of the young; the peculiarities in development of this Entozoon may have an analogous purpose.

The ova of the *Entozoon folliculorum* are bodies of considerable size, and, as I failed in discovering any body of similar proportions within the abdomina of the many hundred animals which I have examined, I came to the conclusion that in their earlier state they were the nucleated cells which so commonly formed a cluster within the caudal extremity of the abdomen, and that these cells underwent development out of the body of the animal. I was strengthened in this view by occasionally finding small masses of these cells in the neighbourhood of the Entozoon. These masses were of an amber colour, and composed of nucleated cells, each of which measured about $\frac{1}{2500}$ of an inch in the long and about one-fourth less in the short diameter. In the vicinity of the masses of small cells I frequently saw cells of somewhat larger size (Plate XVI. fig. 12.) composed of secondary cells, and others, of a more or less oval shape, containing within their investing membrane secondary nucleated cells of various size and in considerable number (Plate XVII. fig. 13.). The measurement of the latter bodies (transition ova) varied between $\frac{1}{1667}$ and $\frac{1}{1000}$ of an inch in the short diameter, and $\frac{1}{1250}$ and $\frac{1}{769}$ in the long axis. The perfect ova are oval in shape, somewhat larger at one end than at the other, about twice the length of their breadth, semitransparent, amber coloured, and composed of nucleated granules or cells inclosed in a thin and yielding membrane. They vary in length from $\frac{1}{500}$ to $\frac{1}{320}$, and in breadth from $\frac{1}{833}$ to $\frac{1}{555}$ of an inch.

The first developmental change observable in the ovum is the disintegration of the tesselated plane of nucleated cells which constitute the surface of the ovum, and lie in contact with its investing membrane. These cells, which are at first polygonal in form, become rounded and larger in size, and the cells of the centre of the ovum acquire a considerable preponderance in bulk over those of the periphery. Subsequently to these changes the cells assume a special arrangement, they become aggregated into a small oblong mass, which is curved at each end, and is not unlike the embryo of higher animals, while a space is formed between the trunk of the little mass and the membrane of the egg. The next stage would seem to be the rupture of the egg-membrane and the expulsion of the embryo, but this process I have not observed in operation, although I have seen on the one hand embryos which appeared to be just released from their investing membrane, while on the other I have detected egg-membranes evidently cast off by ecdysis. In some few of the ova I have observed adipose cells, some large and some small, mingled with the germinal cells.

It is a curious fact, that in the development of the *Entozoon folliculorum*, a remarkable embryonic form is met with which is peculiar to the long variety of the animal, and is not met with in the shorter kind. This embryonic body is elongated, rounded and bulky at one extremity; smaller, somewhat tapering and blunt-pointed at the other, and enlarged towards the middle by the development from one of its sides of two oval-shaped prominences which subside gradually into the larger end and join the smaller end, either at a right or at a receding angle. This peculiarity of form enables us to divide the embryo into a body, which comprises the larger end and these two oval prominences, and a tail, which is the smaller and shorter end; the principal changes in its form taking place, in the course of development, being the elongation of the tail and the enlargement or subsidence of the oval prominences. The dimensions of the embryo are $\frac{1}{312}$ to $\frac{1}{217}$ of an inch in the long, and $\frac{1}{714}$ to $\frac{1}{555}$ in the short diameter. In structure the embryo presents a close analogy with the ovum, being composed of nucleated cells, having the same disposition and appearance, and enclosing in the centre of their mass a number of larger cells. The larger cells correspond in position with the broadest part of the embryo, and extend more or less in proportion to its development into the cephalic and caudal portions. They also vary in their size, the central cells being the largest, while those which surround them are small and more numerous.

The smallest of the ova that I have examined are something less in length than twice their breadth, but, as they progressively enlarge, they undergo a corresponding alteration in their form; they become elongated, they swell towards the centre, and one end acquires a slight predominance in bulk over the other. This change in the form of the ovum converts it into an embryo; in one position the embryo is still oval, the one extremity being somewhat larger than the other, but as soon as it rolls over on its side the prominence of the middle part is perceptible. At this period the tail is shorter than the bulky part, and the latter scarcely presents any trace of division into the two lobe-like protrusions that are subsequently formed. As the embryo progresses in size the lobes become more apparent, and, seen from the front, the entire body is not unlike an ace of clubs with an elongated stalk. The next advance in growth is indicated by a further increase in length of the tail portion, and a more equable enlargement of the rest, so that the subdivision of the convex mass, although still apparent, is less manifest than it had been previously.

The form of embryo just described was that of the specimen which measured $\frac{1}{217}$ of an inch in length. Lying near to this in the same mass of sebaceous substance was another, a very little longer, being only $\frac{1}{200}$ of an inch in length, but different in proportions. It was divisible into a head, a thorax, and a tail-like abdomen. The head was a rounded portion of the mass, distinguished from the rest by a slight constriction, but presenting no distinction of parts. The thorax was oval in shape, largest in the middle, and diminishing towards the ends; and the abdomen was cylindrical, much less in diameter than the thorax, and uniform in size. The animal appeared to be composed internally of an assemblage of cells enclosed in a thin membrane. The cells were all of the same size, or differed but little in this respect, and there was no trace of markings upon any part of the tegumentary covering. There was one character however in this specimen which distinguishes it at once from the embryonic form, and which has induced me to regard it as the first stage of development of the young animal. This character is the presence of three pairs of legs, which are extremely short, and look like conical prolongations of the substance of the animal. In a more advanced stage the divisions of the body become more distinctly defined, and begin to assume the characters by which they are approximated to the perfect animal. The head, for instance, is seen to be composed of two oval-shaped lobes, and a conical central piece, projected at the extremity of the body; the thorax still retains its oval form, but is broader behind than in front, and the abdomen tapers gradually backwards to a rounded point. Other indications of the immature state in more advanced stages are,—the absence of cephalic palpi; the shortness and straitness of the thorax; the absence or small size of the phalanges; the great length of the cylindriform and tapering abdomen; the slightness of the thoracic and abdominal markings; and the confused and cellular structure of the interior. I have found the length of the young animal while possessing only three pairs of legs, to range between $\frac{1}{200}$ and $\frac{1}{59}$ of an inch, while in breadth its measurements were from $\frac{1}{833}$ to $\frac{1}{500}$. After the attainment of four pairs of legs, its length ranged between

$\frac{1}{75}$ and $\frac{1}{50}$ of an inch, and its breadth between $\frac{1}{625}$ and $\frac{1}{555}$; one remarkably long specimen measured $\frac{1}{46}$.

The development of the short variety of the Entozoon is unattended by an intermediate embryonic form. The elements of the head and the feet are produced from the ovum itself, and with very little alteration in the form of the latter. I have already remarked that the largest of the ova become elongated, and if we suppose that the head is produced from one extremity, while three pairs of legs are projected at the sides, we shall have the young form of the animal. The smallest specimen which I have examined was somewhat exceeded in length by the largest of the ova, measuring only $\frac{1}{333}$, while the ovum measured $\frac{1}{320}$ of an inch. And I found a gradual progression in length from that specimen upwards to the more perfect kinds. This early form, like the analogous one of the long variety, possesses only three pairs of legs, which resemble mere protrusions of the external membrane. The head is equally imperfect in form, and the abdominal striæ are not apparent; the internal structure again is a mere assemblage of cells; the changes which ensue during the progressive improvement of this form are,—an elongation of the abdomen, the formation of abdominal rings, and of the thoracic markings. There is one peculiarity which is more remarkable in the young of the short variety than in that of the larger kind, and that is, the very frequent ecdysis. The three-legged form of the short variety measures in long diameter from $\frac{1}{333}$ to $\frac{1}{167}$, and in breadth from $\frac{1}{1111}$ to $\frac{1}{555}$ of an inch.

Like the long variety, the young of the shorter kind has a four-legged as well as a three-legged stadium, the production of an additional pair of legs becoming apparent after the throwing off one of the exuviæ. During this stage the animal begins to assume the general form of the perfect state; the thorax loses its straitened character and becomes rounded and larger; the abdomen becomes longer, and instead of tapering gradually towards the tail, maintains its bulk until near the extremity, when it becomes suddenly smaller, and forms an elongated point. Moreover, during this period the head is more fully formed; the segments of the thorax and legs are more completely developed, and the abdominal rings more distinct. The internal structure is also modified and improved. The measurements of the four-legged stage of the young of the short variety range in length between $\frac{1}{200}$ and $\frac{1}{135}$, and in breadth between $\frac{1}{625}$ and $\frac{1}{555}$ of an inch.

On reviewing the structure of this remarkable animal, I feel again disposed to revert to the position which it should occupy in the animal kingdom; that it is not a member of the class *Insecta* seems proved by its possession of four pairs of legs; that it is not an *Acarus* must be manifest from the preceding description; and that it is not an *Arachnidan* appears to be equally certain. The distinct separation between the head and thorax, the incomplete separation of the latter from the abdomen, the annulate structure of the abdomen, the free movements of the latter, and especially its capability of contraction, both in the longitudinal and transverse direction, are

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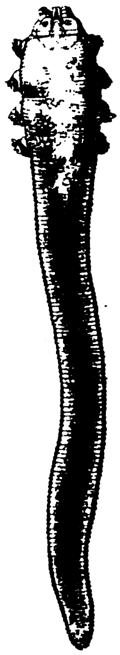

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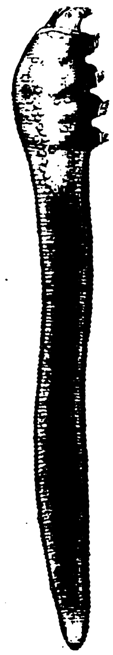

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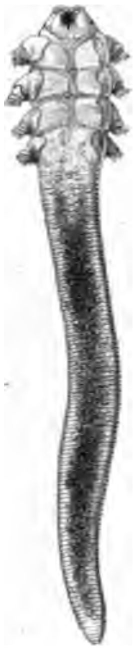

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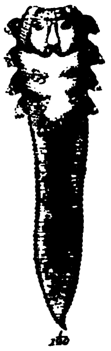

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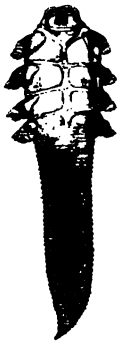

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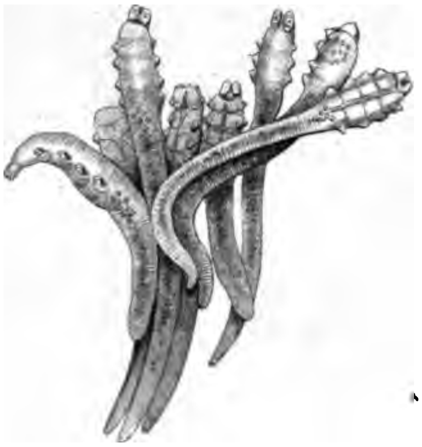

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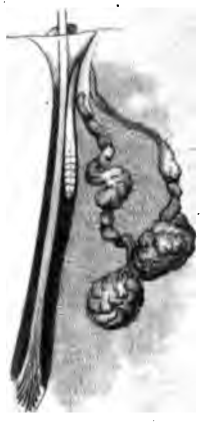

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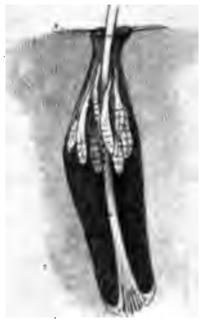

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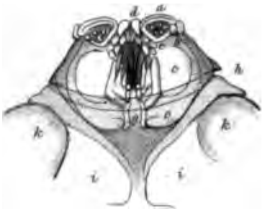

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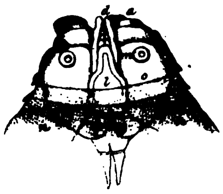

W. Bagg. et Erasmus Wilson, del.t

J. Basire

arguments for regarding it as an *Annelidan*. While, on the other hand, Mr. Gray of the British Museum, to whom I submitted the animal, considers it to be allied to the *Entomostracous Crustacea*, to that group of animals intermediate between worms and insects, of which De Blainville speaks in the following terms:—" Genre d'animaux tellement bizarres au premier aspect, que les zoologistes sont encore fort peu d'accord sur la place qu'ils doivent assigner à ce groupe dans la série animale"*.

Note.—The foregoing paper was first communicated to the Royal Society in December 1842 and was read in March 1843; previously to being again communicated it was remodelled, the facts remaining the same.—E. W.

Explanation of the Plates.

PLATE XV.

The whole of the figures, with a few exceptions stated in the references, are drawn to a scale of one line to the $\frac{1}{2500}$ of an inch.

Fig. 1. A dorsal view of the long variety; showing tegumentary and internal texture. This animal measured $\frac{1}{63}$ of an inch in length.

Fig. 2. A side view of the same.

Fig. 3. A ventral view of the same animal; the mouth is well shown.

Fig. 4. The short variety; a dorsal view, the head retracted, and seen through the transparent integument of the thorax. The specimen measured $\frac{1}{120}$ of an inch in length.

Fig. 5. The same animal; seen upon its ventral surface.

It will be remarked that these figures are not extremes of measurement; but the difference between them is nevertheless very striking. In addition to relative length of abdomen, the caudal extremity forms a conspicuous character.

Fig. 6. A group of animals found in the sebaceous substance of a living person. This and the two following figures are not drawn to a scale.

Fig. 7. A similar group, situated within a hair-follicle.

Fig. 8. This figure represents a hair-follicle, with two sebaceous glands opening into it. An *Entozoon folliculorum* is seen between the cylinder of the hair and the follicle. It must be remembered that the hair is one of the minute downy hairs of the skin.

Fig. 9. The head, viewed upon its under surface.

a. One of the cephalic palpi, curved downwards; its prismoid truncated extremity is seen, as also the phalanges.

b. A spine or tubercle on its penultimate segment.

c. The reniform body. *d.* The antennæ-like palpi.

e. The four labral palpi.

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* Dictionnaire des Sciences Naturelles. Article *Lernée*.

f. The three labial palpi. The row of organs within the palpi are the maxillæ which border the mouth and pharynx.

g. Parts entering into the structure of the pharynx.

h. The boundary lines of the collar.

i, *i*. The first pair of thoracic plates.

k, *k*. The first segments of the anterior pair of legs.

Fig. 10. The head, viewed upon its superior surface.

The letters of reference to *k* are the same as in the preceding figure.

l. The flask-shaped cephalic organ; at the apex of this organ the convexities of the labeal palpi are seen.

m. The eyeball, surrounded by its orbit. *n*. The thoracic carapax.

o. The pointed termination of the flask-shaped organ.

p, *p*. The oval bodies between which it is received, and to which part of the retractor muscle of the head is attached.

PLATE XVI.

Fig. 11. A small mass of ovum-corpuscles? These corpuscles measured $\frac{1}{2500}$ of an inch; they are not drawn to a scale.

Fig. 12. Ovum-corpuscles increased in growth and containing numerous cells. This figure, like the preceding, is not drawn to a scale.

Fig. 13. Three ova, showing progressive growth. The measurements of these ova were $\frac{1}{1250}$, $\frac{1}{833}$ and $\frac{1}{770}$ of an inch.

Fig. 14. An ovum measuring $\frac{1}{500}$ of an inch in length.

Fig. 15. An ovum measuring $\frac{1}{470}$ of an inch.

Figs. 16, 17. Ova measuring $\frac{1}{417}$ of an inch in length.

Fig. 18. An ovum elongated in figure, and measuring $\frac{1}{320}$ of an inch.

Fig. 19. An ovum which has assumed the form of the next stage of development of the Entozoon.

The whole of the ova here represented exhibit structural modifications, having reference to development. This is particularly evident in figs. 16 and 17.

Fig. 20. Embryonic form of the long variety of the Entozoon; fig. 19 exhibits a transition to this form. The figure measured $\frac{1}{312}$ of an inch in length.

Fig. 21. An embryonic form, in a different position to the preceding. The specimen measured $\frac{1}{294}$ of an inch in length.

Fig. 22. An embryonic form in a different view. Length $\frac{1}{238}$ of an inch.

Fig. 23. The largest embryo I have observed. It measured $\frac{1}{217}$ in length.

Fig. 24. An embryo upon the sides of which three pairs of legs are in progress of development. This is the first gradation in the six-legged stage of the long variety. The specimen measured $\frac{1}{200}$ of an inch in length.

Fig. 25. An animal more advanced in growth, and enclosed in exuviæ. This speci-

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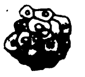
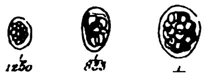


$\frac{1}{1500}$

12

13



$\frac{1}{1250}$ $\frac{1}{833}$ $\frac{1}{770}$

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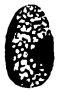

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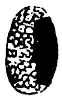

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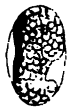

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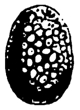

$\frac{1}{417}$

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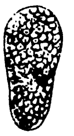

$\frac{1}{320}$

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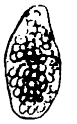

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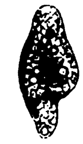

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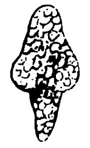

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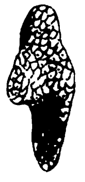

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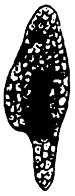

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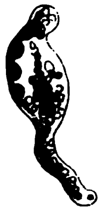

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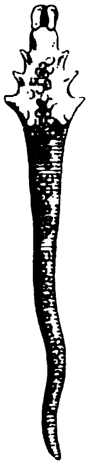

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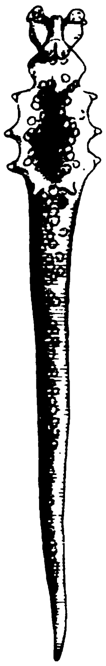

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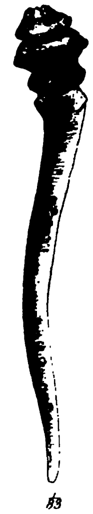

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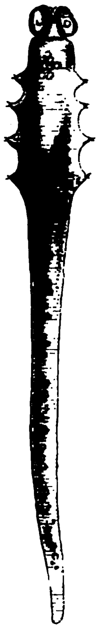

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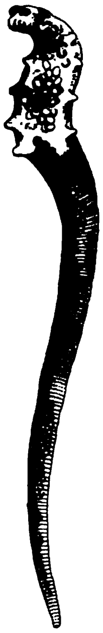

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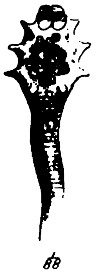

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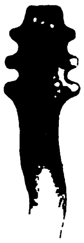

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Erasmus Wilson del^t

J. Basire sc.

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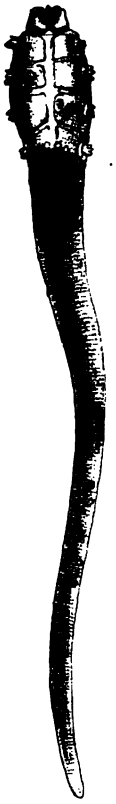

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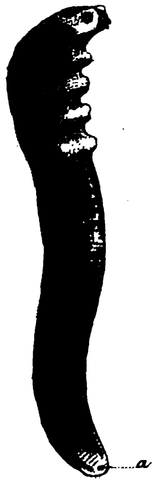

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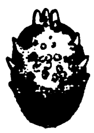

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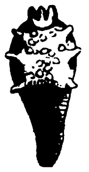

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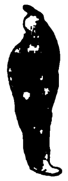

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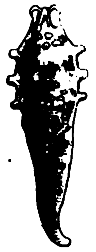

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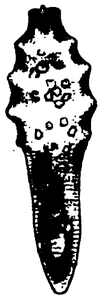

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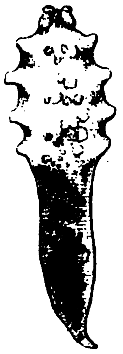

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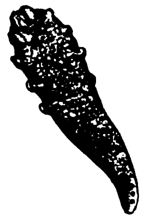

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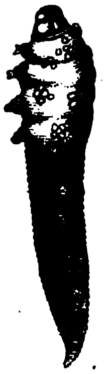

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*Erasmus Wilson. del.*t

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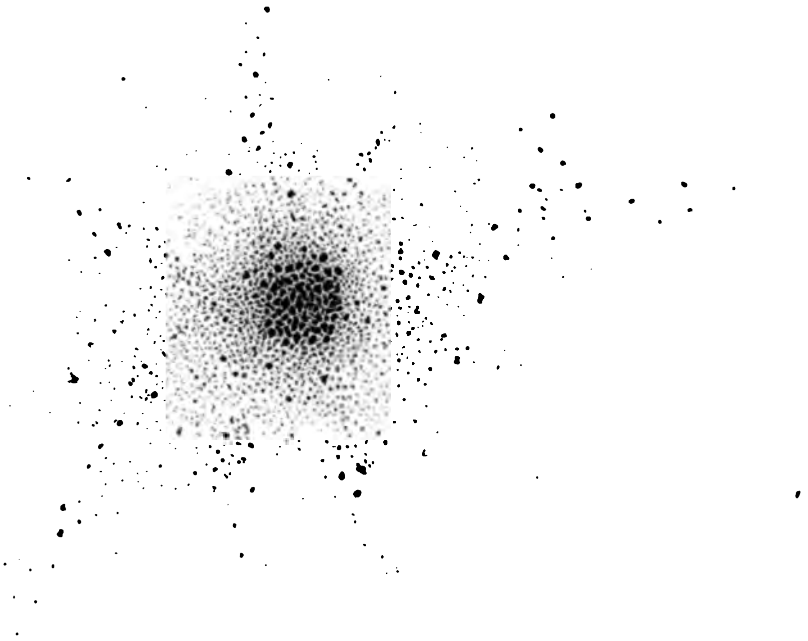

Fig. 88. *R. A.* 21^h 25′. *Dec.* 1° 34′ *South.*

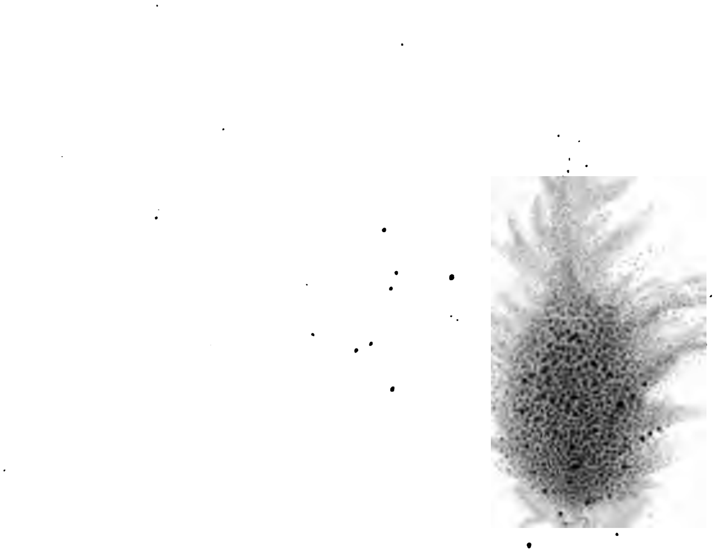

Fig. 81. *R. A.* 5^h 24′. *Dec.* 21° 53′ *North.*

J. Basire

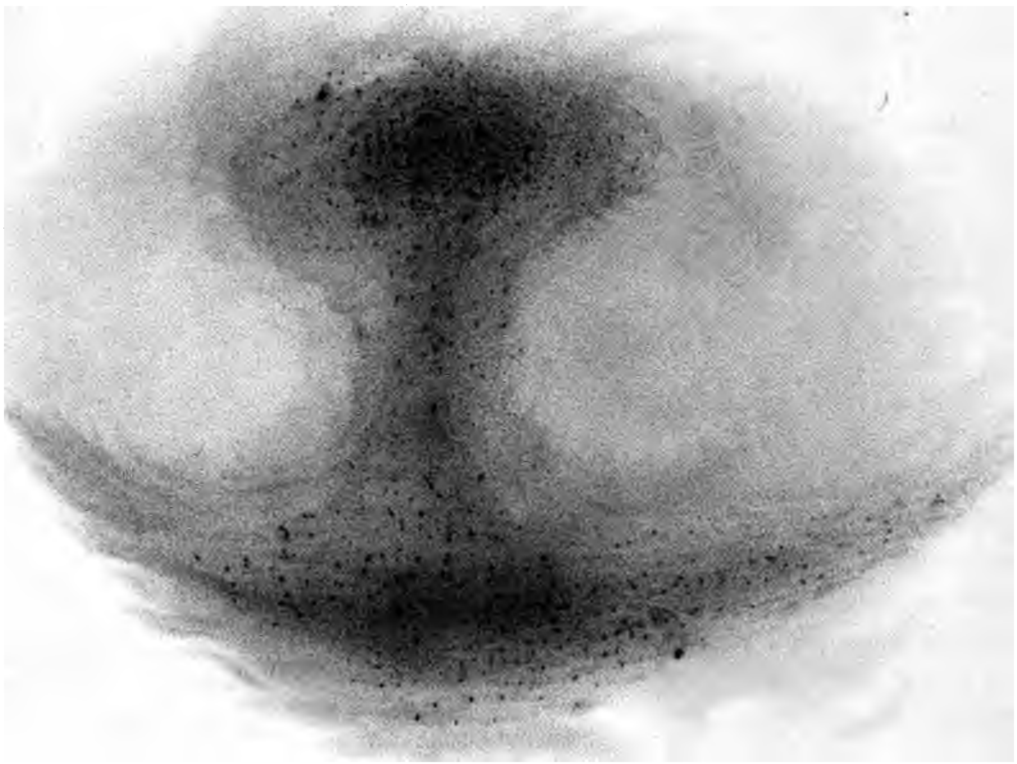

Fig. 26. *R.A.* 19^h 52′ *Dec.* 32° 49′ *North.*

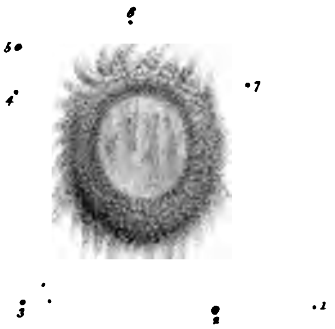

Fig. 29. *R.A.* 18^h 47′ *Dec.* 32° 49′ *North.*

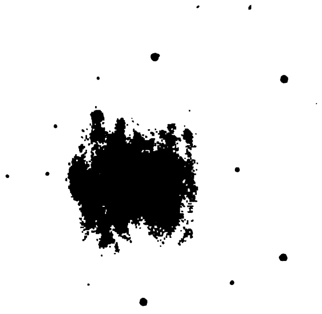

Fig. 47. *R.A.* 20^h 15′ *Dec.* 19° 34′ *North.*

J Basire sc.

XII. *Observations on some of the Nebulæ. By the Earl of* ROSSE, *F.R.S., &c.*

Received June 10,—Read June 13, 1844.

AS every addition, however trifling, to the little we know with certainty respecting the nebulæ can scarcely be considered wholly uninteresting, I have ventured to communicate a few observations made with the speculum of three feet aperture described in the Philosophical Transactions for 1840.

In using that instrument, the object was rather to test its powers, and to decide the merits of progressive experiments, than to seek for astronomical results, and therefore the micrometer was not employed; in every case, however, the sketches were repeatedly compared with the originals, and having usually the advantage of the opinion of one or more friends, and always of that of my assistant, I believe they will be found to be tolerably correct. Without accurate micrometrical measurements any sketch can be of comparatively little value as an astronomical record, since it would be scarcely safe under any circumstances to consider it as decisive evidence, where the question was whether any change had or had not taken place in the general outline or internal structure of a nebula, or in the relative positions of the remarkable stars in or near it. Still measurements to be valuable must be exact; and it would perhaps have been misspent time to have employed the micrometer with an instrument not well suited to the purpose, when there was a prospect of being under the necessity of repeating the same operations again, probably at a very short interval, in making a complete examination of the nebulæ with the instruments now in progress.

From these trifling sketches, however, we may perhaps faintly see some indications of the course which our speculations on the physical structure of the nebulæ are likely to take under the guidance of increasing information. Some estimate may also perhaps be made of the amount of knowledge to be gained by an examination of all the known nebulæ with instruments like the present telescope, which astronomers favourably circumstanced may construct without any very serious difficulty.

The actual time in one year during which a powerful telescope can be used effectively is so short, that where observations must be accompanied by sketches, the progress is necessarily slow; and it is still more so when the micrometrical measurement of faint objects becomes an essential portion of the work. Out of a considerable number of tolerably good working nights there are very few, and even then often but for a short time, when high magnifying powers can be employed; so that upon the whole a great deal cannot be accomplished by one instrument in a limited period. As to the present telescope, it has not been constantly employed. Unless the beginning of the night was favourable nothing was ever done; a regular system of observing would have been quite incompatible with the constant care and attention required in the progress of the more important work, the construction of a telescope of greater power, so that much fewer objects have been examined than would otherwise have been practicable; and even with the great facilities afforded by Sir JOHN HERSCHEL's invaluable catalogue, the whole amount of work done has been no more than the examination of about two-thirds of the figured nebulæ, and a few others in the general catalogue, many of them, or rather, perhaps, most of them, under circumstances but moderately favourable.

The sketches were originally made in the gallery of the telescope, and represent the objects placed as they appeared, not as they actually exist in space. I have copied them without alteration, not thinking that anything would be gained by placing them approximately in their true positions, while they would perhaps be less convenient for future re-examination and correction. The references are to Sir JOHN HERSCHEL's Catalogue.

Plate XVIII. fig. 88 is one of the many well-known clusters; I have selected it merely for the purpose of showing that in such objects we find no new feature, nothing which had not been seen with instruments of inferior power; the stars, of course, are more brilliant, more separated, and more numerous. I fear that no amount of optical power will make these objects better known to us, though perhaps exact measurements may bring out something.

Fig. 81 is also a cluster; we perceive in this, however, a considerable change of appearance; it is no longer an oval resolvable Nebula; we see resolvable filaments singularly disposed, springing principally from its southern extremity, and not, as is usual in clusters, irregularly in all directions. Probably greater power would bring out other filaments, and it would then assume the ordinary form of a cluster. It is studded with stars, mixed however with a nebulosity probably consisting of stars too minute to be recognized. It is an easy object, and I have shown it to many, and all have been at once struck with its remarkable aspect. Everything in the sketch can be seen under moderately favourable circumstances.

Plate XIX. fig. 26, on the contrary, is a difficult object; it requires an extremely fine night and a tolerably high power; it is then seen to consist of innumerable stars, mixed with nebulosity; and when we turn the eye from the telescope to the Milky Way, the similarity is so striking that it is impossible not to feel a pretty strong conviction that the nebulosity in both proceeds from the same cause.

Fig. 29.—The annular nebula in Lyra; 2 is the star in Sir JOHN HERSCHEL's sketch; I have inserted the six other stars as in some degree tests of the power of a telescope. Near star 3 there are two very minute stars seen with great difficulty; the others are easily seen whenever the night is sufficiently good to show the nebula well. The filaments proceeding from the edge become more conspicuous under increasing magnifying power within certain limits, which is strikingly characteristic of a cluster; still I do not feel confident that it is resolvable. I am however disposed to

think that it was never examined when the instrument was in as good order, and the night as favourable, as on the several occasions when the resolvable character of fig. 26 was ascertained.

Fig. 47 is one apparently of another class. It has a star in the centre, and is of unequal brightness; the nebulosity is in patches, and I have sometimes fancied, though probably erroneously, that I could discover in it a faint resemblance to fig. 26. The star in the centre is easily seen, and there is nothing peculiar in its appearance; it is exactly like other stars seen in nebulæ; still it may really be but the brilliant condensed centre of a very remote cluster. I have not, however, detected any gradual increase of brilliancy towards the centre.

Not to multiply sketches which soon may require correction, I shall merely add that in fig. 32 we also find a star in the centre, and in fig. 85 likewise a star in the centre, and many other minute stars in and close to it, so that it is really a cluster. The double nebula (fig. 72) consists of two clusters, between which there is a star easily seen on even an indifferent night. In fig. 49 there are minute stars between and about the three large stars, and I think there can be no doubt it is a cluster. Fig. 25 abounds in stars mixed with nebulosity; I have not seen it on a very fine night, but it was observed by my assistant, and by a gentleman who was with him, and they had no doubt but that the centre was completely resolved. In the little annular nebula, fig. 48, I see nothing remarkable, farther than a star in the north preceding edge; it is tolerably conspicuous, and is about half-way between the exterior and interior circumference of the annulus.

Fig. 45 is a very remarkable object. It is no longer a planetary nebula, but an annular nebula, like that of Lyra, with a similarly fringed edge, though much less distinctly seen: it is oval, but the central portion is not so dark as that of Lyra; it very closely resembles the annular nebula of Lyra seen with an instrument of inferior power.

In several of the other figured nebulæ something has been discovered as to matters of detail. In some we have found perhaps a few minute and apparently accidental stars, in others a larger extent of nebulosity, and consequently a different form of outline, but nothing of sufficient importance to make it desirable further to prolong this paper. It appears to me, however, to be an important fact, that all we have seen strongly confirms the accuracy of Sir JOHN HERSCHEL'S judgement in selecting the nebulæ which he places in the class designated as resolvable. It is important from its bearing on future researches; for where the power of our instruments is insufficient to do more than to bring to light distinctly the peculiar characteristics of resolvability, these once observed with due caution and their reality ascertained beyond doubt, we shall conclude with little danger of error, that the object is really a cluster. We should err, however, were we to assume the converse of the proposition, that the absence of all symptoms of resolvability was evidence conclusive that the object was not a cluster. In some instances, with increasing optical power, the resolvable character has become clearly developed, as in fig. 26, and a further increase of power has shown the object resolved.

It is also perhaps important to observe, that now, as has always been the case, an increase of instrumental power has added to the number of the clusters at the expense of the nebulæ, properly so called; still it would be very unsafe to conclude that such will always be the case, and thence to draw the obvious inference that all nebulosity is but the glare of stars too remote to be separated by the utmost power of our instruments.

The magnifying powers I have usually employed vary from 250 to 800; occasionally much higher powers have been useful; but to see every thing described in this paper, a power of 600 with perfect definition is sufficient.

In my paper on the Reflecting Telescope, in the Philosophical Transactions for 1840, there is an error which I am anxious to take this opportunity of correcting. In page 523, line 14, instead of "to the polisher," it should have been "to the bar which moves the polisher measured on the edge F of the tank." We have always estimated the effect of the excentric G by the space on the edge of the tank traversed by the bar: the number 2·7 was entered down at once from the journal-book, whereas, to have suited it to the form of expression made use of, it should have been reduced to the centre of the polisher.

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